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PROTECTION OF PROPELLERS IN ICE - PHASE II
TP7887E

PREPARED FOR THE
TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA
MAY 1986

By

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OTTAWA, Ontario

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DAVIS FILE NO: C82-177

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LANGUAGE NOTICE

Un sommaire en français de ce rapport est inclus avant la Table des matières.

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Transport Canada / Transports Canada

Development / Développement

REPORT DOCUMENTATION FORM

1. Transport Canada Report No.	2. TDC Project No.	3. Recipient's Catalogue No.
TP 7887E	4949	

4. Title and Subtitle	5. Report Date
PROTECTION OF PROPELLERS IN ICE - PHASE II	May 1986
	6. Performing Organization Report No. 82-177

7. Author(s)	8. Transport Canada File No.
I. Glen, L. Goossens, B. Guthrie, D. Howard, J. Lougheed, S. Mathews, W. Molyneux	D1460-137-2

9. Performing Organization Name and Address	10. DSS File No.
W.R. Davis Engineering Ltd. 1260 Old Innes Road Ottawa, Ontario K1B 3V3	12SD.T8200-2-2588
	11. DSS or Transport Canada Contract No. OSD82-00183

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Transportation Development Centre (TDC) Guy Favreau Complex 200 Dorchester Blvd. West, Suite 601, West Tower Montreal, Quebec H2Z 1X4	Final: 1983-1986
	14. Sponsoring Agency Code TDC 4949

15. Supplementary Notes	16. TDC Project Officer
	R. Dillon/N. Gore

17. Abstract

An experimental evaluation of a protected propulsion system for large, powerful icebreaking ships was undertaken. The system included three propellers located in tunnels with inlet grills and nozzles, and twin low aspect ratio rudders behind each. The concept was evaluated for both its effectiveness in protecting propulsion components and the extent of losses and performance degradation attributable to the extra equipment.

A 1:46 scale model based on a hull concept for the CCG Polar Class was fitted with triple tunnels/nozzles and operated in free running and overload propulsion and manoeuvering tests.

Results of tests showed that open water resistacne was high and would require 2.5 to 3.0 times more shaft power than a conventional open screw system for speeds between 12 and 24 knots. The rudder configuration was most effective and gave excellent turning qualities.

The authors conclude that this system imposes penalties on power requirements that would be unacceptable for a vessel whose operating profile included significant open water transits. A less severe but significant penalty on icebreaking force (10% for 100,000 kW delivered power) was also encountered.

18. Key Words	19. Distribution Statement
Protection; Ice; Propellers; Icebreakers; Tunnels: Nozzles; Grills; Propulsion; Losses; Rudder; Model	Limited number of copies available from the Transportation Development Centre on request

20. Security Classification (of this report)	21. Security Classification (of this page)	22. No. of Pages	23. Price
Unclassified	Unclassified		--

Canada

Transports Canada / Transport Canada
Développement / Development

FORMULE DOCUMENTAIRE DU RAPPORT

1. N° du rapport Transports Canada	2. N° de l'étude — CDT	3. N° de catalogue du destinataire
TP 7887E	4949	

4. Titre et sous-titre	5. Date du rapport
PROTECTION OF PROPELLERS IN ICE - PHASE II	mai 1986
	6. N° du rapport de l'organisme exécutant: 82-177

7. Auteur(s)	8. N° de dossier Transports Canada
I. Glen, L. Goossens, B. Guthrie, D. Howard, J. Lougheed, S. Mathews, W. Molyneux	D1460-137-2

9. Nom et adresse de l'organisme exécutant	10. N° de dossier — ASC
W.R. Davis Engineering Ltd. 1260 Old Innes Road Ottawa, Ontario K1B 3V3	12SD.T8200-2-2588
	11. N° de contrat — ASC ou Transports Canada: OSD82-00183

12. Nom et adresse de l'organisme parrain	13. Genre de rapport et période visée
Centre de développement des transports (CDT) Complexe Guy-Favreau 200 ouest, boul. Dorchester, Suite 601, Tour Ouest Montréal, Québec H2Z 1X4	Final: 1983-1986
	14. Code de l'organisme parrain: CDT 4949

15. Remarques additionnelles	16. Agent de projet — CDT
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17. Résumé

Les travaux dont il est rendu compte ici concernent l'évaluation d'un système expérimental de protection du bloc propulsif d'un brise-glace de forte puissance. Ce système comportait trois hélices sous voûte, des grillages à l'entrée, des tuyères et un gouvernail double à la sortie de celles-ci. Il s'agissait de vérifier l'efficiacité des organes de protection et de mesurer l'amplitude des pertes de performances dues au système lui-même.

Un modèle à l'échelle 1/46 d'une coque destinée aux brise-glace canadiens de classe Polar a été équipé de ce système de protection et soumis à des essais de propulsion non guidée et sous surcharge et de manoeuvre.

Les expériences ont montré une résistance à l'avancement élevée en eau libre, nécessitant une puissance de deux à trois fois supérieure à celle d'un bloc propulsif de type classique, dans la plage des vitesses allant de 12 à 24 noeuds. En revanche, le gouvernail double a été très efficace, donnant d'excellentes qualités manoeuvrières.

Les chercheurs sont arrivés à la conclusion que le système considéré imposerait une surpuissance trop onéreuse dans le cas d'un navire fonctionnant souvent en eau libre. En outre, une dégradation moins grave mais quand même importante 10p. 100 des 100 000 kW de puissance délivrée a été constatée dans la force de déglaçage.

18. Mots-clés	19. Diffusion
Protection, glaces, hélices, brise-glace, voûtes, tuyères, grillages, propulsion, pertes, gouvernail, modèle	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
non classifié	non classifiée		—

Canada

PREFACE

This report is the final phase of work on concepts proposed by Davis Engineering to protect large icebreaking ships from damage to their propellers and steering gear while operating in ice. In the previous phase, unacceptably high drag from the bare hull masked the contribution of protection devices, and it was decided to re-model the aft area prior to retesting for effectiveness and losses.

DAVIS was contracted by the Transportation Development Centre to manage hull and appendage manufacture, testing and analysis. The National Research Council of Canada provided expert services and facilities for model manufacture and testing. DAVIS subcontracted with ARCTEC Canada for Naval Architecture services during lines development, and for analysis of test results. They were assisted by Coldstream Maritime in this latter task.

SUMMARY

This report presents the results and analysis of model tests of a concept for providing propeller protection against ice ingress for large powerful icebreakers. The work represents the second phase of a development study undertaken on behalf of the Transportation Development Centre.

Free running and overload propulsion tests, manoeuvering tests and ice floe visualization tests were performed by National Research Council of Canada on a 1:46 scale model based on on a concept for the CCGS Polar Class icebreaker, fitted with the proposed triple tunnel/nozzle arrangement at the stern. This model incorporated modifications to the stern to improve the flow to the propellers, arising from an earlier series of model tests.

Resistance and propulsion factors have been calculated for the fitted propellers and the effects of increasing propeller pitch on free running and overload propulsion were examined.

Comparison of the results of delivered power with the earlier propeller protection configuration, and the original, conventional triple screw system showed that, while the more recent model showed a 16.4% improvement over the earlier protection concept, both concepts have an average delivered power three times that of the conventional concept in the 12 - 14 knot range. Analysis of the overload data showed that the new concept had 10% less available icebreaking force at 100,000 kW and 18% at 40,000 kW than the conventional open screw model. This was an almost 100% improvement over the earlier protection device.

A wake survey analysis indicates that measured wake from the towed tests is quite different from that calculated from self-propulsion tests, indicating the effect of the concentrated inflow through the tunnels, particularly in the overload-icebreaking condition. This would greatly affect the design of the propellers.

A limited number of controlled tests which visualized the flow of ice pieces, placed in streamlines under the model at points ahead of midships, indicated that ice ingestion to the propellers was most unlikely. While ingestion of small ice pieces may occur when the ship transits a deep ridge or rubble field, or at high speed in thin ice, it is generally concluded that the device is effective in miminimizing ice ingestion to the propellers. However, the likelihood of ice ingestion for this vessel with conventional screws was also shown to be low.

In modified zig-zag manoeuvers, the system, which incorporates twin, high aspect ratio rudders behind each of the three propeller nozzles, proved extremely effective and provided the vessel with excellent turning qualities, the calculated steady turning diameter/length ratio being 3.6 at speeds above 8.0 knots.

The report presents all the model test and propeller data, as well as the analysis. It is concluded that the propeller protection device imposes a severe penalty on open water power requirements that would not be acceptable in a vessel whose operating profile included a significant amount of open water operations. While it is shown that some improvement could be obtained with a higher pitch ratio propeller, this sytem requires as much as three times the power of a conventional open screw system. In the icebreaking mode there is also a severe penalty with the proposed configuration.

The report concludes that this type of propeller protection device shows little promise for the application, and notes that some well-designed propeller nozzle configurations currently in service on Canadian designed vessels operating in the Arctic may be more appropriate in a tripe screw configuration.

SOMMAIRE

Le présent rapport analyse les résultats des essais faits sur le modèle réduit d'un dispositif expérimental de protection du bloc propulsif d'un brise-glace de forte puissance. Il s'agit là de la deuxième phase d'un programme de recherche lancé pour le compte du Centre de développement des transports.

Un modèle 1/46e, représentant un brise-glace canadien de classe Polar, a été équipé du bloc propulsif à trois hélices et du dispositif de protection proposé, puis soumis par le Conseil national de recherches à des essais de propulsion au régime normal et de surcharge, à des essais de manoeuvre et à d'autres visant à visualiser l'écoulement des fragments de glace. La partie arrière de ce modèl avait été modifiée compte tenu des essais précédents, de manière à améliorer l'écoulement vers les hélices.

Les facteurs de résistance et de propulsion ont été dégagés à l'égard des hélices utilisées, tandis que l'effet d'un pas d'hélice plus grand sur la propulsion en régime normal et de surcharge a été approfondi.

La comparaison des résultats autorisés par les deux dispositifs de protection, l'ancien et le plus récent, avec ceux du bloc propulsif sans protection aucune a montré une augmentation de la puissance moyenne délivrée de l'ordre de trois fois, dans la plage des vitesses entre 12 et 14 noeuds et une amélioration de 16,4 p. 100 du dispositif le plus récent sur l'ancien, par rapport au bloc propulsif, en régime de surcharge, le nouveau dispositif accuse une perte dans la force de déglaçage de 10 p. 100 à 100 000 kW et de 18 p. 100 à 40 000 kW, ce qui représente tout de même une amélioration de 100 p. 100 par rapport au dispositif antérieur.

Sur le plan des pertes dues au sillage, il a été constaté que les valeurs résultant des essais de remorquage différaient sensiblement de celles calculées à partir des essais d'autopropulsion, cette différence étant due à la convergence des veines à l'intérieur des voûtes, surtout en régime de surcharge-déglaçage. Cette constatation est de nature à influer considérablement sur le dimensionnement des hélices.

Un nombre restreint d'essais ont été réalisés pour visualiser l'écoulement des fragments de glace placés dans les veines, sous le modèle, en divers endroits entre l'avant et le milieu; il a été observé que le risque de pénétration dans le bloc propulsif était à peu près nul. On en conclut que le système de protection est efficace sur ce plan, bien qu'il soit encore possible que de très petits fragments puissent pénétrer lorsque le navire franchit une crête profonde ou un champ de glaces hummockées, ou bien lorsqu'il avance rapidement dans une glace de faible épaisseur. Cependant, on observe la même aptitude dans le cas du bloc propulsif non protégé.

Le système propulsif complet, qui comporte trois hélices, des tuyères et un gouvernail double à la sortie de chacune, s'est révélé très efficace lors des manoeuvres de marche en zig-zag modifiées, donnant au navire d'excellentes qualités évolutives, le rapport diamètres de giration/longueur en marche continue ayant été calculé à 3,6 aux vitesses supérieures à 8 noeuds.

Le rapport présente l,ensemble des résultats des essais sur modèle et les caractéristiques des hélices ainsi que l'analyse des données. Les chercheurs sont arrivés à la conclusion que le dispositif de protection impose un surpuissance onéreuse à un navire fonctionnant le plus souvent en eau libre, et qu'il nécessite jusqu'à trois fois la puissance délivrée par un bloc propulsif de type classique, le choix d'hélices à pas plus grand n'apportant qu'une très légère amélioration. Cet inconvénient se vérifie même en mode de déglaçage.

Les chercheurs concluent que le type de protection considéré est peu prometteur dans l'aplication envisagée; ils font également observer que certains types de tuyères particulièrement bien conçues, qui équipent des navires "arctiques" de fabrication canadienne, pourraient convenir davantage à un bloc propulsif comportant trois hélices.

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APPENDIX B - Resistance Calculations Based Upon Flat Plate and Form Factor Skin Friction Corrections - Material Supplied by NRC with Letter 11 March 1986.

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NOMENCLATURE

CFM	=	Frictional resistance coefficient for model (unitless)
CTM	=	Total resistance coefficient for model (unitless)
D	=	Propeller diameter (m)
ETAD	=	Propulsive efficiency (unitless)
	=	PD/PE
ETAO	=	Propeller efficiency in open water (removed from the hull) (unitless)
ETAR	=	Relative rotative efficiency of the propeller (unitless). The effect the presence of the hull has on the efficiency of the propeller. The ratio of propeller torque (removed from the hull) to propeller torque (behind the hull).
Fn	=	Froude number based on characteristic length (unitless)
	=	$V/\sqrt{g\ L}$
FP	=	Tow force available to overcome ice resistance (kN)
FPG	=	Gross tow force available to overcome hydrodynamic resistance and ice resistance (kN)
g	=	Gravitational constant (9.806 m/sec)
H	=	Ship's draft (m)
K'	=	Prohaska's form factor (unitless)
K'	=	Nomoto's turning rate index (1/sec)
	=	(L/V) K
KFPGD	=	Gross tow force coefficient for the model at the self propulsion point (unitless)
	=	$FPG/\rho\ N^2\ D^4$
L	=	Ship's Length (m)
N	=	Prohaska's form factor power coefficient (unitless)
N	=	Propeller rotational speed (revolutions/sec)

P	=	Propeller pitch (m)
PD	=	Delivered power (kW). The power delivered to the water by the propulsion system in the "behind" the ship configuration.
PE	=	Effective power (kW). The power required to push the hull through the water.
Q	=	Propeller torque (kN.m)
R	=	Total hull resistance (kN)
RAV	=	Average resistance (kN). The average of the full scale resistance predicted using the flat plate skin friction correction and the form factor viscous scale effect correction.
STD	=	Steady State Turning Diameter (m)
T	=	Nomoto's course keeping index (sec)
T'	=	Nomoto's non-dimensional course keeping index (unitless)
	=	(V/L) T
TH	=	Propeller thrust (kN)
THDF	=	Thrust deduction factor (unitless)
	=	1 - R/TH
V	=	Speed of the ship (m/sec)
VA	=	Speed of advance of the propeller (m/sec). The effective speed of the water in the propeller disc.
VS	=	Speed of the ship (knots)
VX	=	Axial velocity (positive bow to stern) (m/sec)
WFTM	=	Taylor wake fraction for model (unitless)
	=	1 - VA/V
δ	=	Rudder angle (radians)
ρ	=	Water mass density (kg/m^3)
Ψ	=	Yaw angle (degrees)
$\dot{\Psi}$	=	Time derivative of yaw (degrees/sec)
	=	$d\Psi/dt$
$d\dot{\Psi}/dt$	=	Second time derivative of yaw ($degrees/sec^2$)
	=	$d^2\Psi/dt^2$

1. INTRODUCTION

This report covers the second phase of a program to design a propeller protection concept for a Polar Class icebreaker.

The first phase was concerned with the theoretical evaluation of various propeller protection concepts. It included a literature review to find and evaluate these concepts, and is reported in [1]. Phase I concluded by developing a specific concept for a triple screw Polar Class icebreaker such as the proposed CCG POLAR 8. This included the hull strengthening requirements and the effect that propeller protection concepts would have on the propulsion efficiency and ship manoeuvering. This work is reported in [2].

Phase I also included a series of hydrodynamic model tests at NRC's (National Research Council of Canada) clear water tank in Ottawa. During these tests, an excessively high hydrodynamic resistance was measured on the model, and as such, extensive work was performed to determine the source of this high resistance.

As a result of this work, it was decided that to reduce the hydrodynamic resistance, the afterbody of the ship would have to be redesigned to produce 'finer' ship lines. In addition, the propeller protection system required modifications; specifically the tunnel would have to be redesigned to improve the flow characteristics of the ducts, and to reduce flow separation. The grills would also have to be modified. This work is reported in [3].

The previous test program led to Phase II of the project reported herein. The improvements mentioned in [3] were made and the modified model was then retested in NRC's clear water tank. These tests include hydrodynamic resistance, propulsion, wake survey, ice flow and manoeuvering tests.

This report describes the model and its propulsion system, and discusses the resistance, propulsion, and overload tests. The calm water, free running performance and overload performance are predicted from these tests. A comparison between the performance of this model and the earlier model is made. The wake survey, ice flow and manoeuvering tests are then described. Conclusions are made regarding the proposed propeller protection concept, listing its advantages and disadvantages.

2. MODEL DESCRIPTION

The model used for this test program was NRC's model number 362. This model is based on one of the proposed designs for the Canadian Coast Guard's POLAR 8, with modifications to the stern to incorporate the propeller protection scheme. Figure 2.1 shows the body plan drawings of the POLAR 8 without appendages. Detailed drawings of model 362 can be obtained directly from IMD (Institute for Marine Dynamics) either in St. John's, Newfoundland or Ottawa, Ontario

Model 362 was built of laminated wood, at a scale of 1/46. For all testing, the model was essentially the same, with all appendages fitted. During the resistance and wake survey tests, however, the propellers and rudders were removed.

A tripwire, located 5% of the waterline length aft of the forward perpendicular and parallel to the bow profile, was used to create turbulence during these tests. For the ice flow tests, the objective was to understand the ice flow's trajectory. Thus, the ship's boundary layer was considered important, and, as such, the tripwire was not removed.

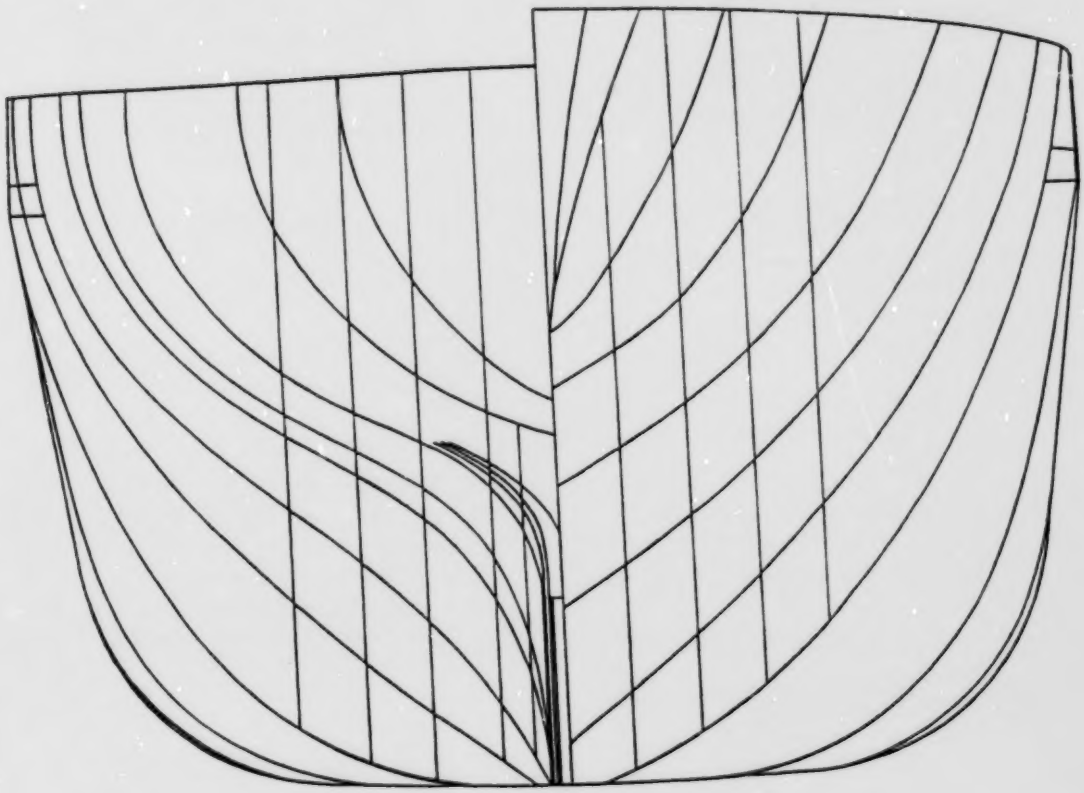
Table 2.1 lists the basic model parameters. Appendix A, Table 1 of this report gives further details of model 362.

TABLE 2.1

MODEL 362 DESCRIPTION

NRC MODEL NO.:	362
MODEL SCALE:	1/46
DISPLACEMENT (F.S.):	68980 tonnes (S.W.)
DRAFT (MIDSHIP):	14.03 m
TRIM (BY STERN):	0.00 m
NUMBER OF PROPELLERS:	3
NUMBER OF RUDDERS:	6

FIGURE 2.1
BODY PLAN DRAWING OF THE POLAR 8 PARENT HULL FORM



3. STERN ARRANGEMENT AND APPENDAGE DESCRIPTION

The propeller protection scheme tested under this program is the nozzle and tunnel arrangement described in [1]. This is a multiple screw in-hull arrangement with the propellers totally enclosed in separate tunnels with guarded bottom intakes. The propellers are located in one plane and a squared off transom stern used along with a wall sided hull form for simplicity.

The parent hull form, described in Section 2, was modified by first removing the center propeller skeg; and fairing the hull lines into the parallel midbody at approximately Station 4 (Station 0 being the aft perpendicular and Station 10 being the forward perpendicular). Three inplane nozzles were then mounted across the stern, appropriately faired into three identical and separate tunnels. Figure 3.1 shows three views of the stern, and Figure 3.2 shows an abbreviated body plan of the tunnel arrangement of model 362.

The propellers used during these tests were NRC stock propellers, cropped to fit in the nozzles. The wing propellers were outward turning when viewed from astern, while the center propeller was right-hand turning. Details of the propellers used are tabulated in Table 3.1, and in greater detail in Table 1 of Appendix A.

TABLE 3.1

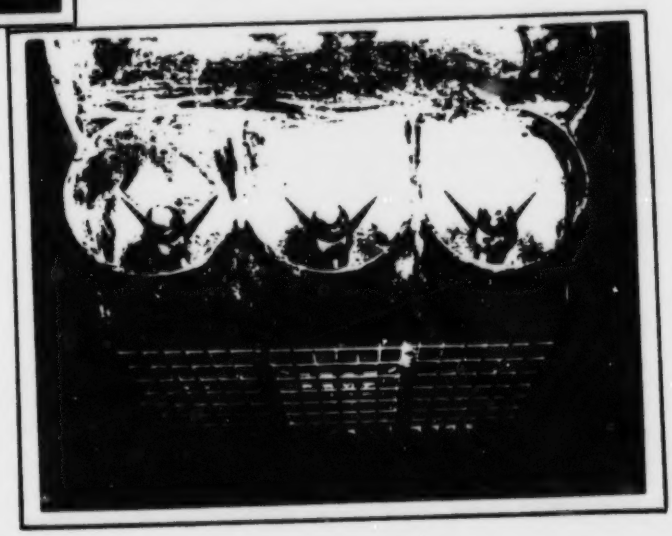
MODEL PROPELLERS USED (NUMBER 74 PROPELLERS)

PROPELLER DIAMETER [1]:	0.1484 m
EXPANDED AREA RATIO:	0.412
NUMBER OF BLADES:	4
ROTATION [2] - WING:	OUTWARDS TURNING
- CENTER:	RIGHT HAND TURNING

FIGURE 3.1
PROPELLER PROTECTION ARRANGEMENT

Propeller Protection Concept

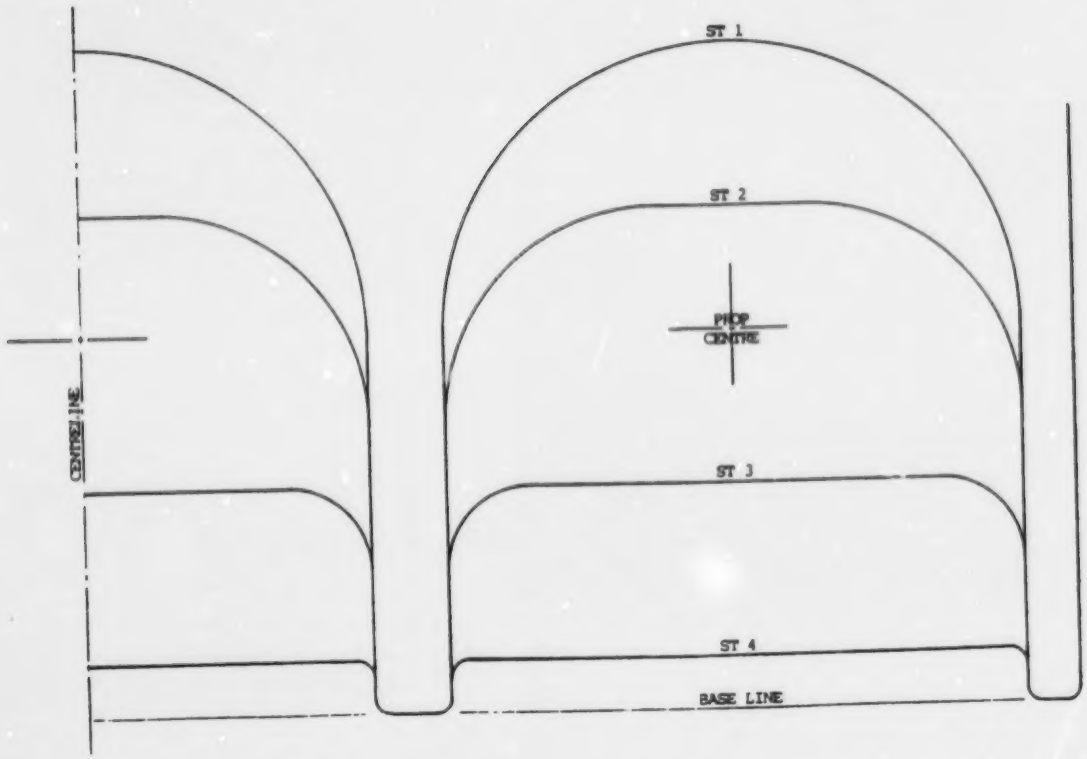
Propeller Tunnel Arrangement (Note: with only 3 of 6 rudders installed)



Ice Protection Grill

Photos courtesy of NRC

FIGURE 3.2
ABBREVIATED BODY PLAN OF TUNNEL ARRANGEMENT



4. MODEL NO. 362 RESISTANCE AND PROPULSION, BOLLARD AND OVERLOAD TEST RESULTS

The reduced model data from the experiments conducted at NRC are reproduced in Appendix A.

The resistance tests were performed with the model being towed from a height of the propeller shafts at midships. The results of these data were used to predict the effective power using the International Towing Tank Conference (ITTC) 1957 skin friction line. The wetted surface area used in this calculation excluded the area of the grills. A blockage correction factor was also included to account for the tank's boundary effects. From the model resistance tests, full scale resistance values have been tabulated at 1 knot intervals, from 4 knots to 26 knots. Both flat plate skin friction and form factor viscous scale effect corrections have been calculated for a correlation allowance equal to zero (see Tables 4 and 16 and Figure 2 of Appendix A). The form factor is (1 - K) and is given by:

$$\frac{CTM}{CFM} = (1 + K) + \frac{Fn^N}{CFM}$$

The form factor associated with the stern duct, with grills, is very high at 2.385 with the corresponding calculated ship resistances being much lower than for the flat plate skin friction corrected values; 25% lower at the higher speeds and 50% lower at the lower speeds. It is noted that both of these standard techniques may be considered as an over simplification for the separation of viscous and wave making effects for Model No. 362, giving results on the one hand too high and on the other hand too low.

In the absence of further detailed data, which would lead to more reliable and meaningful assumptions, however, it was decided to give power predictions based upon the average resistance (RAV) results from these two methods.

The propulsion experiments were carried out in a similar manner as the resistance experiments. The propulsion experiments were carried out using the overload technique with the model being towed/restrained from a point at the height of the propeller shafts at midships.

Again, the ITTC 1957 skin friction line was used to predict the delivered power. During these tests, the thrust, the torque and the rotational speed were measured and averaged for the entire test run. These values are given in Tables 5 to 15, 17 and 18, and Figures 4 and 5 of Appendix A. The thrust deduction factor (THDF), the model's Taylor wake fraction (WFTM) and the propeller's rotational efficiency (ETAT) for the combined propellers are used with the average resistance (RAC) in the power prediction.

Propeller open water tests were also performed at three different rotational speeds covering the range of the linear speeds used in the propulsion experiments (see Table 3 and Figure 1 in Appendix A). No rotational speed effects were observed, and the results given are the average of the three tests conducted.

5. CALM WATER RUNNING FREE (NO OVERLOAD) PERFORMANCE PREDICTIONS, WITH EFFECTS OF PITCH RATIO CHANGES, FOR DESIGN NO. 362

Table 5.1 shows the average ship resistance values and the calculated effective propulsion factors based on the results in Appendix A.

The items in Table 5.1 have been used to calculate the predictions for PE, N, TH (total), Q (total), PD, ETAO and ETAD shown in Table 5.2 for the model propeller number 74, used in the experiments, and for B4.40 series propellers having P/D ratios of 0.8, 1.0, 1.2, and 1.4

There is no optimum P/D ratio for the range considered. ETAO and ETAD improved for all speeds, with increasing P/D.

TABLE 5.1

SHIP RESISTANCE AND EFFECTIVE PROPULSION FACTORS

VS knots	RAV kN	THDF	WTFM	ETAR
12.75	1314	0.064	-0.240	0.898
17.17	2513	0.061	-0.223	0.922
19.20	3211	0.077	-0.217	0.936
21.41	4313	0.082	-0.223	0.945

The B4.40 series propeller with a P/D ratio equal to 0.8 shows an average of 9.8% improvement in ETAD compared with the model propeller number 74.

On increasing P/D from 0.8 to 1.4, a further 11% increase in ETAD is obtained.

Delivered power as a function of speed is shown in Figure 5.1 for a P/D ratio of 0.8 and 1.4 for the B4.40 series propeller.

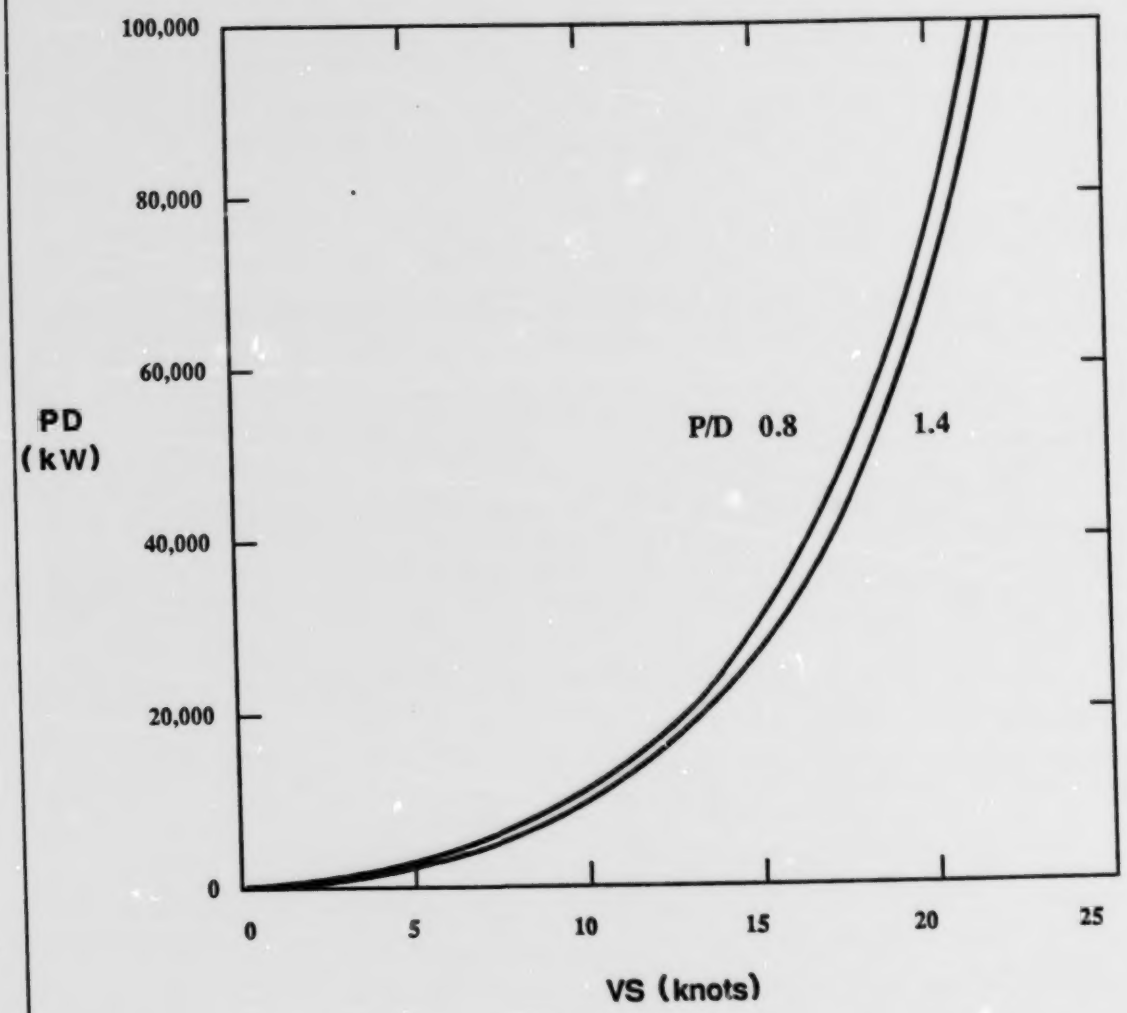
TABLE 5.2

PROPULSION PARAMETERS FOR MODEL PROPELLER NUMBER 74
AND B4.40 SERIES P/D VALUES 0.8, 1.0, 1.2 AND 1.4

VS knots	P/D	PE kW	N RPM	TH kN	Q kN.m	PD kW	ETAO	ETAD
	no. 74		100.3		1962	20610	0.618	0.418
	0.8		97.0		1823	18520	0.687	0.465
12.75	1.0	8619	82.5	1403	1990	17190	0.740	0.502
	1.2		71.2		2261	16850	0.755	0.512
	1.4		63.7		2504	16700	0.762	0.516
	no. 74		134.4		3553	50010	0.627	0.444
	0.8		130.7		3466	47440	0.661	0.468
17.17	1.0	22200	111.0	2676	3608	41940	0.747	0.529
	1.2		95.9		4131	41470	0.756	0.535
	1.4		86.0		4580	41270	0.759	0.538
	no. 74		151.1		4549	71970	0.620	0.441
	0.8		146.7		4288	65870	0.678	0.482
19.20	1.0	31720	125.0	3477	4674	60710	0.735	0.522
	1.2		107.9		5301	59890	0.745	0.530
	1.4		97.0		5852	59440	0.751	0.538
	no. 74		171.3		5909	106010	0.631	0.448
	0.8		166.3		5567	96930	0.691	0.490
21.41	1.0	47480	141.8	4697	6072	90150	0.743	0.527
	1.2		122.7		6951	89300	0.750	0.532
	1.4		110.5		7709	89233	0.751	0.532

Figure 5-1

DELIVERED POWER SPEED CURVES



6. BOLLARD AND OVERLOAD (ICE RESISTANCE) PERFORMANCE PREDICTION, WITH EFFECTS OF PITCH RATIO CHANGES, FOR DESIGN NO. 362

Tables 6.1 and 6.2 show the average ship resistance values (Section 4) and the calculated effective propulsion factors, for PD values of 100,000 kW and 40,000 kW, based on the results in Appendix A, for the bollard and overload tests.

The items in Tables 6.1 and 6.2 have been used to calculate the predictions for N, Q, TH, the gross force available to overcome ice and hydrodynamic resistances (FPG), the net force available to overcome ice resistance (FP) and a figure of merit

$$\frac{KFPGD}{(10KQ)}\ 2/3\ ,$$

for 40,000 kW and 100,000 kW delivered power, for the various propellers. These are shown in Tables 6.3 and 6.4.

The figure of merit is a measure of the gross force availble (per propeller) for a given delivered power.

It can be seen that this latter decreases with increases in ship speed and P/D for a given delivered power. It increases with the increase of delivered power.

The B4.40 propeller with a P/D ratio of 0.8 gives, on an average, for a ship velocity betwen 0 and 8.56 knot, 5.8% more gross available force than propeller number 74. Going from a P/D ratio of 0.8 to 1.4 for the B4.40 series propellers there is, on an average, a 4.9% loss in performance.

In comparison with figures of merit for the bollard tests with propellers in open water (removed from the ship's hull), on an average, for the same propeller pitch ratio, the resultant experiments with the propeller behind the hull vary slightly. The presence of the hull and ducts does not change the results significantly.

A B4.40 propeller with a P/D ratio of 0.8 performs better than propeller number 74, both running free (9.8% better) and in overload conditions (5.8%). This, of course, is not surprising since the propeller number 74 was only adapted as a test convenience, to obtain the basic data.

Since P/D effects are in opposition in self propulsion, running free, and overload conditions, the operational requirements would dictate the choice of propellers for a specific application.

TABLE 6.1

SHIP RESISTANCES AND OVERLOAD
EFFECTIVE PROPULSION FACTORS

PD = 100,000 kW

VS knots	RAV kN	THDF	VA knots	WFTM	ETAR
0	0	-0.350	14.85	-	0.973
4.4	173	-0.241	16.66	-2.786	0.958
8.56	568	-0.170	18.47	-1.159	0.946

TABLE 6.2

SHIP RESISTANCES AND OVERLOAD
EFFECTIVE PROPULSION FACTORS

PD = 40,000 kW

VS knots	RAV kN	THDF	VA knots	WFTM	ETAR
0	0	-0.358	11.20	-	0.963
4.4	173	-0.210	13.18	-1.996	0.944
8.56	568	-0.087	15.14	-0.769	0.929

TABLE 6.3

OVERLOAD PROPULSION PARAMETERS
AND FORCES FOR PROPELLER
NUMBER 74 AND B4.40 SERIES
P/D VALUES 0.8, 1.0, 1.2 AND 1.4

PD = 100,000 kW

VS knots	P/D	N RPM	Q kN.m	TH kN	FPG (Gross) kN	FP (Net) kN	KFPGD / (10kQ)$^{2/3}$
0	No. 74	143.2	6668	6989	9434	9434	0.614
	0.8	144.1	6626	7217	9745	9745	0.634
	1.0	126.5	7550	7134	9631	9631	0.626
	1.2	112.9	8460	6984	9430	9430	0.613
	1.4	102.5	9313	6759	9125	9125	0.593
4.4	No. 74	146.2	6533	6508	8076	7903	0.525
	0.8	146.8	6503	6888	8550	8377	0.556
	1.0	128.5	7428	6782	8417	8244	0.548
	1.2	114.1	8367	6654	8258	8085	0.537
	1.4	103.8	9203	6478	8040	7867	0.523
4.4	No. 74	146.2	6533	6508	8076	7903	0.525
	0.8	146.8	6503	6888	8550	8377	0.556
	1.0	128.5	7428	6782	8417	8244	0.548
	1.2	114.1	8367	6654	8258	8085	0.537
	1.4	103.8	9203	6478	8040	7867	0.523
8.56	No. 74	149.6	6384	6042	7071	6503	0.460
	0.8	150.3	6355	6500	7605	7052	0.495
	1.0	130.5	7316	6394	7480	6912	0.486
	1.2	115.5	8268	6327	7403	6835	0.481
	1.4	105.1	9087	6175	7225	6657	0.470

TABLE 6.4

OVERLOAD PROPULSION PARAMETERS
AND FORCES FOR PROPELLER
NUMBER 74 AND B4.40 SERIES
P/D VALUES 0.8, 1.0, 1.2 AND 1.4

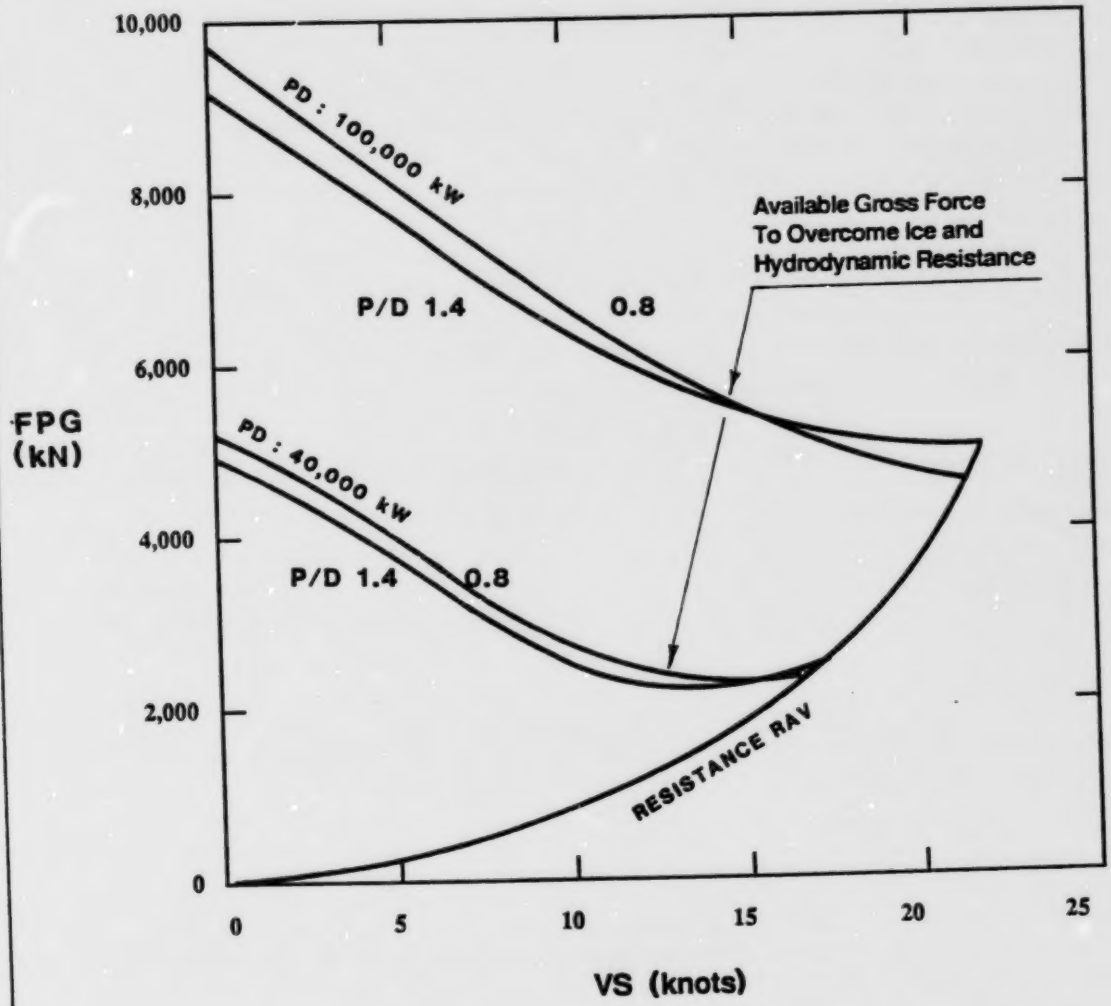
PD = 40,000 kW

VS knots	P/D	N RPM	Q kN.m	TH kN	FPG (Gross) kN	FP (Net) kN	KFPGD / (10kQ)$^{2/3}$
0	No. 74	105.7	3614	3720	5051	5051	0.605
	0.8	106.4	3588	3852	5231	5231	0.627
	1.0	93.3	4093	3802	5162	5162	0.618
	1.2	83.2	4591	3729	5064	5064	0.607
	1.4	75.6	5052	3644	4949	4949	0.593
4.4	No. 74	109.2	3498	3343	4045	3872	0.485
	0.8	104.4	3492	3534	4276	4103	0.512
	1.0	95.5	3999	3560	4308	4135	0.516
	1.2	84.8	4504	3486	4218	4045	0.505
	1.4	77.0	4960	3394	4107	3934	0.492
8.56	No. 74	113.2	3374	2981	3240	2672	0.388
	0.8	113.0	3383	3247	3530	2962	0.423
	1.0	98.2	3890	3261	3545	2977	0.423
	1.2	86.4	4421	3233	3515	2947	0.421
	1.4	78.7	4855	3174	3450	2882	0.413

The available gross forces for the B4.40 propellers at a P/D ratio of 0.8 and 1.4, are plotted in Figure 6.1 to illustrate these effects.

Further to propeller selection based upon model experiments and series data, a final propeller design would consider the flow in the duct in more detail, as well as cavitation and strength criteria to arrive at section lengths and shapes, and would involve the use of modern propeller vortex theory.

Figure 6-1
AVAILABLE GROSS FORCE at TWO DELIVERED POWER LEVELS



7. COMPARISON OF POWER AND PERFORMANCE FOR DESIGN NO. 362 AND PREVIOUS DESIGNS

All of the models and results in the development of the propeller protection ducts, skegs and grills leading up to Model No. 362 are described in [1, 2, 3, 4, 5, 6] and Appendices A and B of the present report.

Model 299 was the parent form for the development program which was a conventional type triple screw polar icebreaker design.

Model 299C represents an early development of the design, which was fully equipped with propeller protective appendages and grills, and for which complete resistance and propulsion data are available as given in [5]. The various appendage refinements that were made had a relatively small effect until the development of Model No. 362, where more substantial gains have been made.

7.1 Comparisons of Clearwater Performance

Table 7.1 gives values of effective and delivered power, and propulsive efficiency for model numbers 299, 299C and 362 for speeds of 12, 16, 20 and 24 knots.

It can be seen that the protective devices increased the effective power of Model 299C compared with Model 299 by an average factor of 2.9. The delivered power of Model 299C is, on average, 3.5 times that of Model 299.

The propellers of Model 299C had D = 6.826 m and P/D = 1.275 with finite section lengths at the tips. The propellers of Model 299 had D = 7.25 m and P/D = 0.64.

Model 299C was operating at a more favourable open water efficiency and the reduction in propulsive coefficient (ETAD) for this model compared with Model 299, as shown in Table 7.1, is due to the overriding decrease in hull efficiency for Model 299C.

Model 362 with the redesigned stern and propeller protection arrangements, shows an average 16.4% improvement in the delivered power compared with Model 299C. Both of these models were fitted with the same propellers. It should be noted, however, that Model 362 still has an average delivered power, over the speed range 12 - 14 knots, of nearly three times that of Model 299.

For interest, comparisons with the MV ARCTIC clear water powers as found in (7) are also made in Table 7.1. Model 299 has the same length but higher beam and draft than the MV ARCTIC. The displacement of Model 299 is 80% higher than for the MV ARCTIC.

TABLE 7.1

CLEARWATER (NO ICE OVERLOAD)
MODEL NO. 362 POWER COMPARIONS WITH PREVIOUS DESIGNS

MODEL		V_s knots 12	16	20	24	AV.
	PE kW	2506	6115	13467	33899	
299	ETAD	0.420	0.474	0.518	0.533	0.486
	PD kW	5967	12901	25998	63600	
	PE	8053	19729	40586	76808	
299C	ETAD	0.431	0.399	0.386	0.385	.400
	PD	18684	49446	105145	199501	
	PE/PE(299)	3.213	3.226	3.014	2.266	2.930
	PD/PD(299)	3.131	3.833	4.044	3.137	3.536
	PE	7191	17933	36753	71730	
362	ETAD	0.411	0.437	0.445	0.445	0.435
	PD	17496	41037	82591	161191	
	PE/PE(299)	2.870	2.933	2.729	2.116	2.662
	PD/PD(299)	2.932	3.181	3.177	2.534	2.956
	PE	1433**	4221**	14130**		
MV*	ETAD	0.56	0.56	0.56		0.56
ARCTIC		av.	av.	av.		
(FROM	PD	2559	7538	25233		
[7])	PE/PE(299)	0.572	0.690	1.049		0.770
	PD/PD(299)	0.429	0.584	0.970		0.661

* Based on tests conducted by NRC on models of the M.V. Arctic.

** Flat plate skin friction corrected results reduced by 9% to give average with form effect corrected results.

Note: Effective powers are based on means of flat plate and form factor skin friction corrections.

As expected, the MV ARCTIC delivered powers are lower than for Model 299, being on an average 66% of those for Model 299. A surprising fact is that the MV ARCTIC effective and delivered power increases to the same as those for Model 299 at 20 knots.

7.2 Comparisons of Overload (Icebreaking Force) Performance

Tables 7.2 and 7.3 give the available forces (FP) to break ice for 100,000 kW and 40,000 kW delivered powers respectively.

The average losses in FP, associated with the propeller protection, for Model 299C compared with Model 299 in the speed range 0 - 8 knots are 18% for 100,000 kW and 23% for 40,000 kW. The open water data thrusts for the different propellers of these vessels at low speed would be very similar when also considering the differences in the diameter, and so the reduced performance of 299C is due to hull and protection devices effects.

Model 362 shows a marked improvement over Model 299C. For Model 362 the average ice force reductions compared with Model 299, over the speed ragne 0-8 knots, are 10% for 100,000 kW and 18% for 40,000 kW delivered powers respectively.

TABLE 7.2

OVERLOAD FORCE (FP) AVAILABLE TO BREAK ICE
FOR PD = 100,000 kW

		V_s Knots			
	MODEL	0	4	8	AV.
FP	299	9920	8876	7884	
	299C	8962	7325	5752	
(kN)	362	9433	7971	6592	
FP/FP(299)	299C	0.903	0.825	0.730	0.819
	362	0.951	0.898	0.836	0.895

TABLE 7.3

OVERLOAD FORCE (FP) AVAILABLE TO BREAK ICE
FOR PD = 40,000 kW

		V_s Knots			
	MODEL	0	4	8	AV.
FP	299	5511	4762	3850	
	299C	4967	3860	2339	
(kN)	362	5053	3930	2702	
FP/FP(299)	299C	0.901	0.810	0.608	0.773
	362	0.917	0.825	0.702	0.815

8. WAKE SURVEY EXPERIMENTS, MODEL 362

The NRC measured data is given in Appendix A, Tables 19-34 and Figures 6-25.

The wake survey tests were performed by rotating a rake positioned in the propeller disc through 360 degrees. The rake consisted of four five-hole pitot tubes, each positioned at a different radius. Each pitot tube would give the three velocity components by measuring the pressure differentials. Each run had the rake at one set angular position. Following each test, the rake's angle was changed and the test repeated. By combining the velocity components of each test, velocity profiles and contours were obtained.

The survey was conducted for speeds of 8 knots and 16 knots for the port shaft (starboard same by symmetry) and the center shaft. Measurements were recorded at four fractional radii: 0.324, 0.512, 0.701 and 0.890 meters.

For these fractional radii the axial, tangential and radial velocities as ratios of the ship speed are tabulated and plotted for intervals around the screw disc; 0°C (or 360°) representing the upright position and 90° representing the outboard position for the wing propellers. (Appendix A Tables 19-34 and Figures 6 to 17).

For both 8 and 16 knot ship speeds and for both the center and the wing propeller positions, contours of Taylor Wake Fraction and vectors of resultant tangential and radial flow ratios were plotted (Figures 18 to 25 of Appendix A).

For both the wing and center propeller locations the circumferential and radial distributions of axial flow, VX/V, are in keeping with what one would expect with a normal twin or triple screw vessel of this design without the skegs (forming ducts) and struts. The towed model wake survey data would normally be used directly for the detailed propeller sections design. This does not apply with the special propeller protection appendages or this vessel, because when shelf propelled, the flow to the propellers is concentrated in the ducts formed by the appendages, and inflow velocities are much higher than indicated by the towed model wake survey. Also, the overload considerations associated with icebreaking options are important in the propeller design for this type of vessel. The inflow is even higher under these conditions.

The average of the towed model wake survey axial velocity ratio inflow, VX/V, is around 0.86. The self propulsion clear water (no overload) analysis value is 1.23. The overload values from the self propellered overload tests are as follows:

PD 100,000 kW

Ship Spped, Knots	4.4	8.56
VX/V	3.79	2.16

PD 40,000 kW

Ship Speed, Knots	4.4	8.56
VX/V	3.0	1.77

9. ICE FLOW EXPERIMENTS, MODEL NO. 362

These experiments and the results are described in Section 2.5 of [8], and the results are illustrated in Appendix A, Figures 26 to 29. Section 2.5 of [8] is reproduced below:

"2.5 Ice Flow

> Experiments were carried out to determine the track of pieces of ice around the outside of the hull; in particular, to see if the ice pieces would stick in the protection devices. The model was tested in a high discharge flume tank,such that the model was stationary and the water moved past the model. Ice was injected into the water by hand at two locations on the hull. These were both approximately 50 cm forward of midships at the centreline, and one-quarter beam on the starboard side. The ice pieces used were of various sizes, but all derived from the same ice sheet with a nominal thickness of 3.8 cm for the model. The water speeds chosen corresponded to the maximum and minimum velocities required to maintain a water level which gave a good angle of view on the underside of the model.
>
> In these experiments, no attempt was made to see if ice would actually get into this location.
>
> The results of the ice flow tests are summarized in Figures 26 to 29 of Appendix A. In view of the visual nature of the testing, no attempt was made at a detailed analysis of the results. However, the presentation does show quite clearly the preferred track of the ice pieces around the hull. The only test condition where there was a high tendency for the ice to stick in the protection devices was the combination of the lowest water speed and the highest propeller revolutions. Unfortunately, this is also the condition most likely to be encountered during icebreaking operations. The results also showed that the ice is more likely to get stuck at the lip of the duct than in the grills alone. In general, the smaller pieces of ice had a greater tendency to get stuck than the larger ones".

Tests were carried out at ship speeds of 5 knots and 6.6 knots and at shaft speeds corresponding to 88 rpm and 177 rpm. A shaft speed of 88 rpm would represent a total delivered power somewhat less than 20,000 kW and 177 rpm would correspond to a total delivered power of approximately 150,000 kW.

The thickness of the ice pieces corresponded to 1.75 m full scale with lengths varying from 2.8 m to 10.6 m and widths varying from 2.3 m to 7.4 m. In some of the thirty-five tests smaller broken pieces were also released.

The average full scale sample length and width was 6.9 m by 4.6 m. Seventeen tests were made at the very high power condition for the two ship speeds. Only seven of these high power tests indicated a tendency for the ice to flow along under the vessel past the grills. In only one of these tests did some small ice pieces enter the grills.

Even with the strategic placement of the ice pieces for entering the propeller ducts, the ice generally flowed clear of the propeller system. It is considered that the possibility of ice flowing into these regions is small, and only small pieces would enter the grills in any event. If ice should reach these bottom positions the likelihood is that this would only occur in deep ridge ramming situations or, rarely, in broken ice fields.

The only test where there was a high probability of having ice stick in the protection device was the combination which would also occur most frequently in reality. The combination of high propeller speed with low ship speed would cause the ice to stick. These tests also showed that ice was more likely to get stuck on the lip rather than the grills, and that the smaller ice pieces had a greater tendency to get stuck than the larger ones.

The propellers on the Model 362 were deeper than those of the MV ARCTIC: a ship of similar length. This latter vessel showed no tendency during many level ice trials for ice to enter the propeller duct as described in [9].

Some main particulars of the two vessels are shown in Table 9.1. The measurements of ship draft, propeller tip depth and propeller transverse depth are also given.

Other work concerned with propeller ice ingestion in level icebreaking has indicated that if this were to occur at all it would probably occur at higher ship speeds and in thinner ice sheets. Some of the level ice trials, with no ice ingestion, for the MV ARCTIC were carried out at ship speeds greater than 6 m/s [9].

TABLE 9.1

HULL AND PROPELLER DIMENSIONS (m)

	MODEL NO. 362	MV ARCTIC
LENGTH BETWEEN PERPENDICULARS:	200	196.6
BEAM	35.16	22.86
DRAFT (H)	14.03	10.97
PROPELLER DIAMETER (D)	6.83	5.27
H - D/2	10.617	8.335
H - D	7.204	5.700

10. MANOEUVERING, ZIG ZAG EXPERIMENTS, MODEL NO. 362

The manoeuvering tests were carried out in the clear water towing tank at NRC. The model was self-propelled and free-running (no attachment to the carriage), and was instrumented to measure the model heading and the rudder angle. The model was accelerated to speed, using its own propulsion system along one side of the basin. Following several ship lengths of steady speed, a preselected rudder angle was applied. The rate of change of the rudder angle was modelled from typical values of a prototype ship. The full scale rudder turn rate was set at 20 seconds for "hardover to hardover". Once a preselected heading was reached, the rudder angle was reversed. This sequence continued as many times as possible down the length of the basin.

Modified standard zig zag manoeuvers for rudder angles of ± 30° and for heading angles, at rudder changes, of ± 10° and ± 5° were carried out. The model was equipped with the twin high aspect ratio rudders behind each propeller at the end of each propeller duct.

Values of T and K from the experimental data and the corresponding non-dimensional coefficients T' and K' from Nomoto's equation:

$$T \frac{d\dot{\Psi}}{dt} + \dot{\Psi} = K \delta \quad \text{(see references [10])}$$

are shown in Table 35 of Appendix A. Typical manoeuver results are plotted in Figures 30 and 31 of Appendix A. The calculated values for K and T derived from the zig zag tests can be used to predict the steady state turning diameter from the expression:

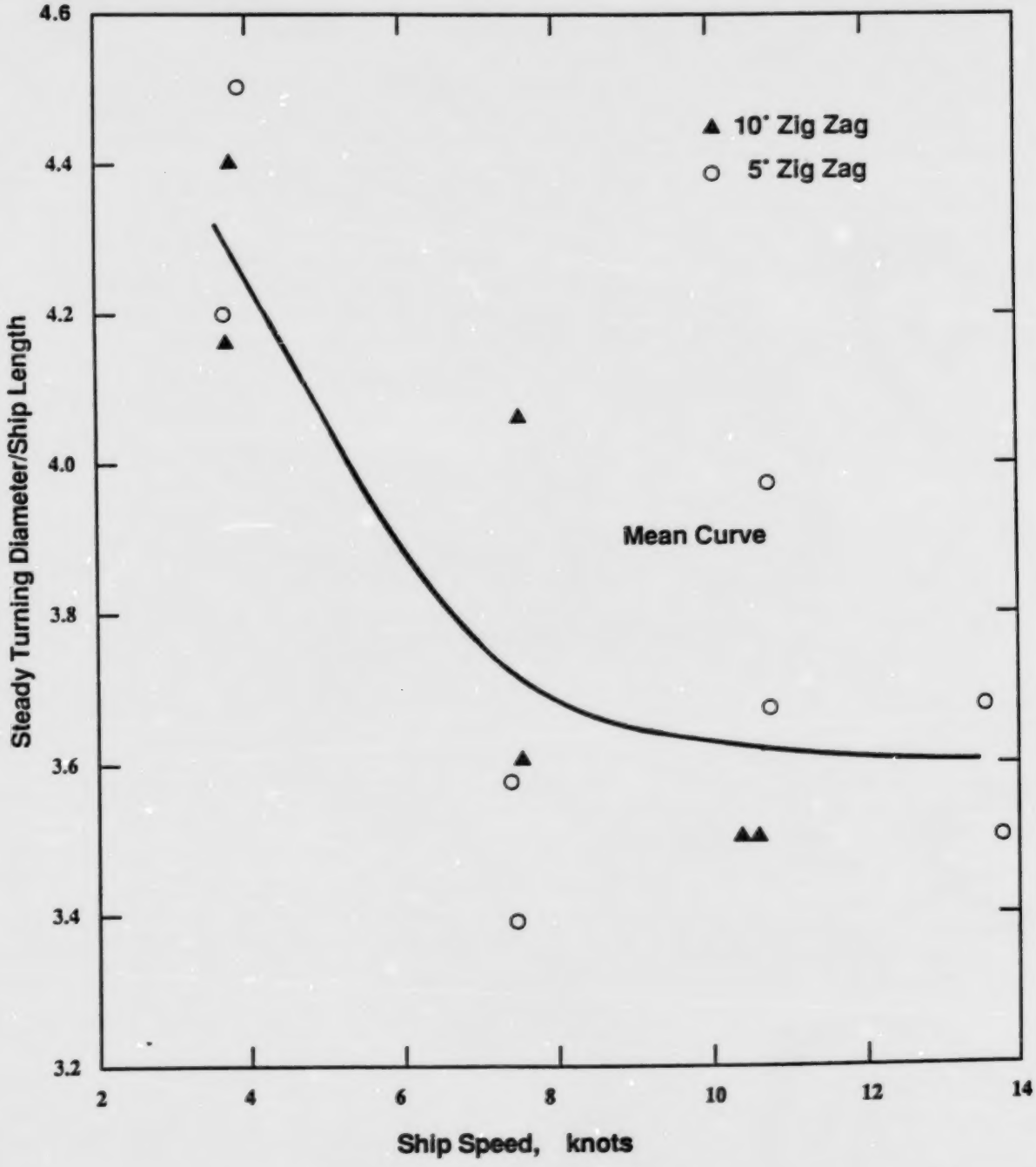
$$\frac{STD}{L} = \frac{2V}{K\delta L}$$

Steady running diameter/ship length ratios, based on these results are given in Table 35 of Appendix A. These turning diameter ratios versus ship speed are plotted in Figure 10.1 and a mean curve is drawn through the points.

The steady turning diameter/length ratio decreases almost linearly from 4.3 to 3.8 over speeds of 3.5 to 6.7 knots and reaches a steady value of 3.6 at 13.7 knots. The twin high aspect ratio rudders behind each propeller are clearly very effective, and give the vessel excellent turning qualities.

Figure 10-1

TURNING DIAMETER RATIO VS. SHIP SPEED



11. CONCLUDING REMARKS

The dilemna regarding scale effect corrections for the models equipped with propeller protection devices, and having high resistances is discussed in Section 4. It was decided to consider resistance predictions based upon a mean of those from flat plate and form effect viscous corrections.

Resistance data and the associated delivered powers and propulsion coefficients in clear water for Model 362, the final development model of the series, are compared with a fully protected previous development model, No. 299C, and the original polar conventional form Model No. 299 in Section 7.1 and on Table 7.1.

Even though Model 362 shows a major improvement over Model 299C, the delivered shaft power required in the speed range of 12 to 24 knots is still, on average, three times that for Model No. 299 which has the same main dimensions.

For a vessel required to transit long clearwater passages these powers and the associated fuel requirements would impose an enormous operational penalty.

Comparisons of available icebreaking forces for Model 362 with previous designs are made in Section 7.2 and in Tables 7.2 and 7.3. Although Model 362 shows a marked improvements over Model 299C there are still losses in icebreaking forces compared with Model 299. These amount over the speed range 0 to 8 knots, on an average, to 10% for 100,000 kW delivered power and 18% for 40,000 kW. These performance losses, although not appearing to be as dramatic as those in clear water, are nevertheless considered as operationally severe.

Section 5, Table 5.2 and Figure 5.1 show how the performance of Model No. 362 could be improved in clear water with changes in propeller particulars. Since the diameter of the propellers is fixed by the duct size, the effect of pitch ratio is examined. The B4.40 propellers with P/D ratio of 1.4 would reduce delivered power, compared to those obtained with the test propellers, over the speed range of 13 to 21 knots by an average of 22%. Even equipped with propellers of this equivalent performance, the delivered powers in this speed range are still 2.5 times those for Model No. 299.

Section 6, Tables 6.3 and 6.4 give the effects of propeller design changes for Model No. 362 in the overload mode. Here the lower P.D ratio of 0.8 shows the best advantage giving, over the speed range 0 to 8 knots, an average 5.8% more icebreaking force for powers of 40,000 kW and 100,000 kW. With this improvement the thurst losses compared with Model No. 299 are 5% and 13% for 100,000 kW and 40,000 kW respectively.

Section 9 comments on the potential for propellers and propeller system ice ingestion at 20,000 kW and 150,000 kW. It is concluded that this is low. It is also concluded that in level icebreaking the possibility of ice ingestion for this vessel without propeller protection is also very low.

These considerations coupled with the power penalties associated with the propeller protection scheme, do not pose a good case for considering this type of propeller protection.

The design performance benefits associated with well designed propeller-nozzle systems, but having adequate immersion, have been demonstrated on the MV ARCTIC as detailed in [7]. Consideration should be given to these systems for the triple screw designs assumed in this study.

The manoeuvering results of Section 10 and Figure 10.1 show the rudders configuration of Model No. 362 to be most effective, giving excellent turning qualities.

12. REFERENCES

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APPENDIX A
REDUCED MODEL DATA
FROM NRC REPORT TR-HYD-02 BY W.D. MOLYNEUX

"PROTECTION OF PROPELLERS IN ICE: RESULTS OF EXPERIMENTS WITH MODEL 362 AND PROPELLERS 74L, R, C"

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LIST OF SYMBOLS

Resistance and Propulsion Experiments

CA	Increment resistance coefficient for model-ship correlation
CF	Specific viscous resistance coefficient
CR	Specific residuary resistance coefficient
CTM(t)	Specific total resistance coefficient for model at temperature (t)°C
CTS	Specific total resistance coefficient for ship at specified sea temperature
CTVOL	Resistance displacement coefficient at specified sea temperature $R/\rho v^2 \Delta^{2/3}$
D	Propeller diameter, m
ETAD	Propulsive efficiency
ETAH	Hull efficiency
EATO	Propeller efficiency in open water
ETAR	Relative rotative efficiency
FD	Towforce applied to a model in self-propulsion test at ship self-propulsion point (positive aft), N
FN, Fn	Froude number based on characteristic length
FNVOL	Speed displacement coefficient $v/\sqrt{g\nabla^{2/3}}$
FP	Pull or towing force of a ship, KN
J	Advance coefficient of propeller, VA/ND
JB	Advance coefficient in self-propulsion tests based on KT identity with propeller open water tests. $JB = N\sqrt{D/g}$
JO	Advance coefficient in self-propulsion tests based on thrust identity with propeller open water tests JO=VA/ND
JOS	Advance coefficient predicted for ship based on thrust identity between model and ship propellers.

LIST OF SYMBOLS (cont'd)

JV	Apparent advance coefficient based on ship speed JV=V/ND
KFD(t)	Tow force coefficient for model at ship propulsion point at average temperature of propulsion test, (t)°C, KFD = $FD/\rho N^2 D^4$
KQ	Torque coefficient
KQO	KQ from open water tests at JO.
KQOS	KQ from open water tests predicted for ship propeller at JOS.
KT	Thrust coefficient of propeller
KTOS	Thrust coefficient predicted for ship based on thrust identity between model and ship propellers
N	Rate of revolution, per second.
PE	Effective power, kW.
PD	Delivered power, kW.
Q	Torque, kNm.
R	Total resistance, kN
TH	Propeller thrust, kN.
THDF	Thrust deduction factor.
V	Speed, m/sec.
VA	Speed of advance of propeller, m/sec
VS	Speed of ship, knots.
WFTM	Taylor wake fraction determined from KT identity for model.
WFTS	Taylor wake fraction determined from thrust identity for ship.
ZETO	Static thrust coefficient $KT/2^{1}/^{3}\pi KQ^{2}/^{3}$
V	Volume of displacement of ship, m^3

LIST OF SYMBOLS (cont/d)

Wake Survey Experiments

r	Radius of pitot tube head, m.
R	Propeller radius, m.
THETA	Angular position of wake survey head, degrees
V	Ship velocity, positive forwards, m/sec
VR	Radial velocity, positive towards shaft centreline, m/sec.
VT	Tangential velocity, positive counterclockwise looking forward, m/sec.
VX	Axial velocity, positive bow to stern, m/sec.

Zig-Zag Experiments

K	Nomoto turning rate index, 1/sec.
K'	Non-dimensional turning rate index, (L/V) K
L	Ship length, m.
STD	Steady turning diameter, m
T	Nomoto course keeping index, sec
T'	Non-dimensional course keeping index, (V/L) T.
δ	Rudder angle
Ψ	Yaw rate, degrees/sec.

STANDARD VALUES

g	Acceleration due to gravity,	9.8066 m/sec^2
ρ	Density of water, salt water at 15°C,	1025.88 kg/m^3
	fresh water at 15°C	998.84 kg/m^3

INTRODUCTION

The following data was produced by the National Research Council of Canada, Institute of Marine Dynamics, Ottawa, Canada, under contract to Davis Engineering Limited. Details of the test methods, test conditions and interpretation of results have been included in the body of the accompanying report, which refers to this data. Minimal additional changes have been made to facilitate publication with TDC.

Table 1

SUMMARY OF MODEL PARAMETERS
MODEL 362

MODEL DESCRIPTION

SCALE	1/46
MATERIAL	WOOD, PAINT FINISH, SANDED
DESCRIPTION	PROTECTION OF PROPELLERS IN ICE, FITTED WITH RUDDERS, SHAFTS, BRACKETS, STUB BOSSINGS, AND GRILLS.

TURBULENCE STIMULATORS

TYPE	TRIPWIRE
LOCATION	5 PERCENT AFT OF FORE PERPENDICULAR AT WATERLINE, PARALLEL TO BOW PROFILE

APPENDAGES (Full Scale Details)

NUMBER OF RUDDERS	6
RUDDERS STOCKS	7.01 m FORWARD OF AFT PERPENDICULAR 5.0, 12.61, and 22.61 m FROM CENTRELINE
SPAN	7.107 m.
CHORD (CONSTANT)	1.932 m.
NUMBER OF PROPELLERS	3
NUMBER OF PROPELLER SHAFTS	3
SHAFT RAKE, UPWARDS	0 DEGREES
SHAFT RAKE, INWARDS	0 DEGREES
TYPE OF SHAFT	OPEN
TYPE OF SUPPORT	A-BRACKETS, 1 PER SHAFT
PROPELLER CENTRES	0 and 17.61 m FROM CENTRELINE 9.78 m ABOVE KEEL

PROPELLER DESCRIPTION

PROPELLER NUMBER	74L, 74R, 74C
DESIGN DESCRIPTION	IMD STOCK PROPELLER, WITH CROPPED BLADE TIPS
DIAMETER (m)	6.826
EXPANDED AREA RATIO	0.412
NUMBER OF BLADES	4
ROTATION (WINGS)	OUTWARDS
(CENTRE)	RIGHT HAND

FULL SCALE DETAILS

MODEL CONDITION	DISPLACEMENT TONNES (S.W.)	DRAUGHT MIDSHIPS (METRES)	TRIM BY STERN (METRES)	WSA (m^2)
DESIGN	68980	14.03	0.0	10661.8

MODEL 362
SUMMARY OF EXPERIMENTS

MODEL NUMBER	CONDITION	PROPELLER NUMBER	CONDITION	SPEED RANGE (KNOTS)	TEST DESCRIPTION
RESISTANCE					
362	Design	-	-	4 - 26	---
SELF PROPULSION					
362	Design	74	Design	4.4 - 21.4	Propulsion & Overload
	Design	74	Design	0	Bollard Pull
WAKE SURVEY					
362	Design	-	Centre Shaft	8, 16	---
362	Design	-	Port Shaft	8, 16	---
ICE FLOW EXPERIMENTS					
362	Design	74	Design	5, 6.6	50% Full Power
362	Design	74	Design	5, 6.6	100% Full Power
MANOEUVRING EXPERIMENTS, 30 DEGREE RUDDER ANGLE					
362	Design	74	Design	4 - 10.5	10° Heading Angle
				4 - 13.6	5° Heading Angle

PROPELLER 74

RESULTS OF OPEN WATER TESTS

MODIFIED STOCK DESIGN

P/D=0.847

J	KT	10KQ	ETAO
0.000	0.343	0.385	0.000
0.025	0.337	0.380	0.035
0.050	0.331	0.374	0.071
0.075	0.325	0.368	0.105
0.100	0.318	0.362	0.140
0.125	0.311	0.356	0.174
0.150	0.303	0.350	0.207
0.175	0.295	0.344	0.239
0.200	0.287	0.337	0.271
0.225	0.278	0.330	0.302
0.250	0.269	0.323	0.332
0.275	0.260	0.316	0.361
0.300	0.251	0.308	0.389
0.325	0.241	0.300	0.416
0.350	0.232	0.292	0.442
0.375	0.222	0.284	0.467
0.400	0.212	0.275	0.490
0.425	0.202	0.266	0.513
0.450	0.192	0.257	0.534
0.475	0.181	0.247	0.554
0.500	0.171	0.238	0.572
0.525	0.160	0.227	0.588
0.550	0.149	0.217	0.603
0.575	0.138	0.206	0.615
0.600	0.127	0.195	0.625
0.625	0.116	0.183	0.631
0.650	0.105	0.171	0.634
0.675	0.093	0.159	0.631
0.700	0.081	0.146	0.622
0.725	0.070	0.133	0.604
0.750	0.057	0.119	0.573
0.775	0.045	0.105	0.525
0.800	0.032	0.091	0.448
0.825	0.019	0.076	0.324
0.850	0.005	0.060	0.115

RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

SHIP LENGTH	224.25	m
DISPLACEMENT	68980	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
SEA TEMPERATURE	15.0	deg C
TEST DATE	20-DEC-85	

SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	FNVOL	CTVOL X100
4.00	388	189	0.044	10.848	6.415	8.143	0.103	5.250
5.00	723	281	0.055	10.316	6.085	7.763	0.129	5.005
6.00	1182	383	0.066	9.788	5.712	7.350	0.155	4.739
7.00	1786	496	0.077	9.337	5.385	6.991	0.180	4.508
8.00	2602	632	0.088	9.095	5.247	6.826	0.206	4.401
9.00	3723	804	0.099	9.064	5.303	6.859	0.232	4.423
10.00	5172	1005	0.110	9.095	5.410	6.946	0.258	4.479
11.00	6936	1226	0.121	9.099	5.481	6.999	0.283	4.513
12.00	9012	1460	0.132	9.062	5.503	7.004	0.309	4.516
13.00	11392	1703	0.143	8.982	5.477	6.964	0.335	4.490
14.00	14183	1969	0.154	8.926	5.468	6.942	0.361	4.476
15.00	17691	2293	0.165	8.992	5.578	7.040	0.386	4.539
16.00	21969	2669	0.176	9.126	5.753	7.203	0.412	4.645
17.00	26356	3014	0.186	9.101	5.765	7.205	0.438	4.645
18.00	31165	3366	0.197	9.048	5.747	7.177	0.464	4.628
19.00	37064	3792	0.208	9.106	5.837	7.257	0.489	4.679
20.00	44243	4300	0.219	9.254	6.016	7.427	0.515	4.789
21.00	52729	4881	0.230	9.453	6.243	7.647	0.541	4.931
22.00	62316	5506	0.241	9.648	6.464	7.860	0.567	5.068
23.00	73079	6176	0.252	9.836	6.678	8.067	0.593	5.201
24.00	84149	6816	0.263	9.928	6.794	8.175	0.618	5.271
25.00	99488	7736	0.274	10.288	7.176	8.551	0.644	5.514
26.00	121075	9052	0.285	10.973	7.883	9.252	0.670	5.965

RESULTS OF SELF PROPULSION EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS KNOTS	12.754	17.166
Fn	0.140	0.188
FNVOL	0.329	0.442

MODEL PROPULSION DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KFD(15.0)	-0.074	-0.074		-0.071	-0.071	
JV	0.542	0.542		0.548	0.548	
KT	0.077	0.085		0.081	0.089	
10KQ	0.166	0.160		0.163	0.162	
JO	0.708	0.692		0.702	0.684	
10KQO	0.142	0.150		0.145	0.154	
WFTM	-0.306	-0.276		-0.281	-0.249	
THDF			0.055			0.045
ETAR	0.852	0.940		0.892	0.950	

PREDICTIONS FOR SHIP WITH MODEL TEST PROPELLER

PE KW			10774.			27100.
PD KW	8841.	8504.	25849.	20480.	20414.	61309.
N RPM	106.3	106.3		141.7	141.7	
TH KN	542.1	597.6	1737.3	1002.9	1105.1	3213.2
Q KNm	793.8	763.6	2321.0	1380.3	1375.9	4132.1
WFTS	-0.306	-0.276		-0.281	-0.249	
ETAO	0.617	0.626		0.621	0.629	
ETAD			0.417			0.442
JOS	0.708	0.692		0.702	0.684	
KTOS	0.077	0.085		0.081	0.089	
10KQOS	0.142	0.150		0.145	0.154	

RESULTS OF SELF PROPULSION EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

S KNOTS	19.202	21.408
n	0.211	0.235
NVOL	0.495	0.552

MODEL PROPULSION DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KED(30.0)	-0.070	-0.070		-0.067	-0.067	
JV	0.548	0.548		0.539	0.539	
KT	0.083	0.092		0.086	0.095	
10KQ	0.161	0.164		0.163	0.167	
JD	0.697	0.679		0.690	0.671	
10KQD	0.148	0.157		0.151	0.161	
WFTM	-0.273	-0.240		-0.280	-0.245	
THDF			0.061			0.068
ETAR	0.915	0.957		0.928	0.961	

PREDICTIONS FOR SHIP WITH MODEL TEST PROPELLER

PE KW			38404.			56529.
PD KW	28452.	28917.	86285.	41661.	42773.	127207.
N RPM	158.6	158.6		179.5	179.5	
TH KN	1289.9	1424.3	4138.6	1717.2	1895.3	5507.8
Q KNm	1713.2	1741.2	5195.7	2216.0	2275.1	6766.3
WFTS	-0.273	-0.240		-0.280	-0.245	
ETAO	0.623	0.630		0.626	0.632	
ETAD			0.445			0.444
JOS	0.697	0.679		0.690	0.671	
KTOS	0.083	0.092		0.086	0.095	
10KQOS	0.148	0.157		0.151	0.161	

RESULTS OF BOLLARD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTRE PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTRE PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER

BOLLARD DATA FOR TEST PROPELLER IN OPEN WATER

CENTRE PROPELLER KT	0.343	10KQ	0.385
WING PROPELLER KT	0.343	10KQ	0.385

MODEL BOLLARD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KED(15.0)	0.717	0.717		0.731	0.731	
JB	1.170	1.170		1.470	1.470	
KT	0.175	0.175		0.180	0.179	
10KQ	0.259	0.250		0.261	0.252	
JO	0.490	0.489		0.479	0.480	
10KQO	0.241	0.242		0.246	0.245	
THDF			-0.364			-0.358
ETAR	0.930	0.969		0.940	0.974	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

PD KW	6837	13163	20000	13659	26341	40000
N RPM	84.2	84.2		105.7	105.7	
TH KN	765.5	768.2	2301.8	1241.5	1238.9	3719.2
Q KNm	775.9	746.8	2269.6	1233.8	1189.7	3613.3
FP KN			3139.5			5052.5
VA knots	9.120	9.093		11.190	11.212	
ZETO	0.504	0.518		0.515	0.527	
JOS	0.490	0.489		0.479	0.480	
KTOS	0.175	0.175		0.180	0.179	
10KQOS	0.241	0.242		0.246	0.245	

RESULTS OF BOLLARD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTRE PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTRE PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER

BOLLARD DATA FOR TEST PROPELLER IN OPEN WATER

CENTRE PROPELLER KT	0.343	10KQ	0.385
WING PROPELLER KT	0.343	10KQ	0.385

MODEL BOLLARD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
EFD(15.0)	0.738	0.738		0.743	0.743	
JB	1.682	1.682		1.850	1.850	
KT	0.182	0.181		0.183	0.182	
10KQ	0.260	0.253		0.259	0.254	
J0	0.473	0.475		0.470	0.472	
10KQ0	0.248	0.247		0.249	0.249	
THDF			-0.357			-0.355
ETAR	0.955	0.976		0.962	0.977	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

PD KW	20322	39678	60000	26982	53018	80000
N RPM	121.0	121.0		133.1	133.1	
TH KN	1646.5	1639.6	4925.7	2006.1	1998.2	6002.5
Q KNm	1604.1	1566.0	4736.1	1936.3	1902.3	5741.0
FP KN			6686.2			8136.3
VA knots	12.656	12.703		13.832	13.882	
ZETO	0.524	0.530		0.529	0.533	
JOS	0.473	0.475		0.470	0.472	
KTOS	0.182	0.181		0.183	0.182	
10KQOS	0.248	0.247		0.249	0.249	

RESULTS OF BOLLARD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTRE PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTRE PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER

BOLLARD DATA FOR TEST PROPELLER IN OPEN WATER

CENTRE PROPELLER KT	0.343	10KQ	0.385
WING PROPELLER KT	0.343	10KQ	0.385

MODEL BOLLARD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KFD(15.0)	0.743	0.743		0.740	0.740	
JB	1.992	1.992		2.114	2.114	
KT	0.184	0.183		0.185	0.184	
10KQ	0.259	0.255		0.260	0.256	
JO	0.468	0.470		0.466	0.468	
10KQO	0.250	0.249		0.251	0.250	
THDF			-0.350			-0.339
ETAR	0.964	0.977		0.964	0.977	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

PD KW	33692	66308	100000	40444	79556	120000
N RPM	143.2	143.2		152.1	152.1	
TH KN	2335.5	2326.2	6987.9	2644.6	2632.4	7909.4
Q KNm	2246.4	2210.5	6667.5	2540.0	2498.1	7536.2
FP KN			9432.5			10587.9
VA knots	14.816	14.872		15.662	15.732	
ZETO	0.531	0.534		0.532	0.535	
JOS	0.468	0.470		0.466	0.468	
KTOS	0.184	0.183		0.185	0.184	
10KQOS	0.250	0.249		0.251	0.250	

RESULTS OF OVERLOAD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUM74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
NO BLOCKAGE CORRECTION APPLIED

VS KNOTS	4.400	4.400
Fn	0.048	0.048
FNVOL	0.113	0.113

MODEL OVERLOAD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KED(15.0)	0.427	0.427		0.506	0.506	
JV	0.227	0.227		0.182	0.182	
KT	0.135	0.140		0.148	0.153	
10KQ	0.234	0.217		0.239	0.228	
JO	0.584	0.570		0.554	0.542	
10KQO	0.202	0.208		0.215	0.220	
WFTM	-1.576	-1.518		-2.041	-1.973	
THDF			-0.187			-0.210
ETAR	0.864	0.960		0.899	0.966	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

			5329			9154
PE KW	7011	12989	20000	13762	26238	40000
PD KW	87.8	87.8		109.2	109.2	
N RPM	642.8	670.5	1983.8	1088.0	1127.3	3342.6
TH KN	762.1	706.0	2174.1	1204.1	1147.8	3499.7
Q KNm			2125.2			3814.9
FP KN						
WFTS	-1.576	-1.518		-2.041	-1.973	
ETAO	0.619	0.613		0.605	0.598	
ETAD			0.266			0.229
JOS	0.584	0.570		0.554	0.542	
KTOS	0.135	0.140		0.148	0.153	
10KQOS	0.202	0.208		0.215	0.220	

RESULTS OF OVERLOAD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUM74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
NO BLOCKAGE CORRECTION APPLIED

VS KNOTS	4.400			4.400		
Fn	0.048			0.048		
FNVOL	0.113			0.113		

MODEL OVERLOAD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KFD(15.0)	0.545	0.545		0.569	0.569	
JV	0.160	0.160		0.146	0.146	
KT	0.154	0.159		0.158	0.163	
10KQ	0.242	0.234		0.243	0.237	
JO	0.539	0.527		0.530	0.518	
10KQO	0.221	0.226		0.225	0.230	
WFTM	-2.365	-2.291		-2.623	-2.544	
THDF			-0.224			-0.234
ETAR	0.915	0.969		0.926	0.970	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

PE KW			12467			15476
PD KW	20461	39539	60000	27125	52875	80000
N RPM	124.2	124.1		136.1	136.1	
TH KN	1467.6	1516.3	4500.3	1809.6	1866.3	5542.2
Q KNm	1573.8	1520.6	4615.0	1903.4	1855.0	5613.3
FP KN			5278.8			6608.2
WFTS	-2.365	-2.291		-2.623	-2.544	
ETAO	0.597	0.590		0.591	0.584	
ETAD			0.208			0.193
JOS	0.539	0.527		0.530	0.518	
KTOS	0.154	0.159		0.158	0.163	
10KQOS	0.221	0.226		0.225	0.230	

RESULTS OF OVERLOAD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUM74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
NO BLOCKAGE CORRECTION APPLIED

VS KNOTS	4.400	4.400
Fn	0.048	0.048
FNVOL	0.113	0.113

MODEL OVERLOAD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KFD(15.0)	0.587	0.587		0.601	0.601	
JV	0.136	0.136		0.128	0.128	
KT	0.161	0.166		0.163	0.168	
10KQ	0.245	0.240		0.246	0.242	
JO	0.523	0.512		0.518	0.506	
10KQO	0.228	0.233		0.230	0.235	
WETM	-2.841	-2.758		-3.033	-2.945	
THDF			-0.241			-0.247
ETAR	0.933	0.971		0.938	0.972	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

PE KW			18278			20928
PD KW	33768	66232	100000	40430	79570	120000
N RPM	146.1	146.2		155.0	155.0	
TH KN	2126.1	2190.7	6507.4	2424.4	2494.7	7413.7
Q KNm	2206.4	2163.4	6533.1	2491.2	2451.8	7394.8
EP KN			7845.7			9016.6
WETS	-2.841	-2.758		-3.033	-2.945	
ETAO	0.587	0.580		0.584	0.576	
ETAD			0.183			0.174
JOS	0.523	0.512		0.518	0.506	
KTOS	0.161	0.166		0.163	0.168	
10KQOS	0.228	0.233		0.230	0.235	

RESULTS OF OVERLOAD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUM74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
NO BLOCKAGE CORRECTION APPLIED

VS KNOTS	8.558	8.558
En	0.094	0.094
ENVOL	0.220	0.220

MODEL OVERLOAD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KED(15.0)	0.134	0.134		0.280	0.281	
JV	0.419	0.419		0.342	0.342	
KT	0.101	0.109		0.120	0.128	
10KQ	0.213	0.181		0.219	0.202	
JO	0.658	0.640		0.616	0.599	
10KQO	0.167	0.176		0.187	0.195	
WFTM	-0.571	-0.529		-0.802	-0.752	
THDF			-0.023			-0.087
ETAR	0.785	0.973		0.854	0.967	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

PE KW			7593			14268
PD KW	7413	12587	20000	14083	25917	40000
N RPM	92.4	92.4		113.2	113.2	
TH KN	532.8	576.4	1685.6	953.5	1014.1	2981.7
Q KNm	766.5	650.7	2067.9	1187.9	1093.0	3374.0
FP KN			982.1			2498.1
WFTS	-0.571	-0.529		-0.802	-0.752	
ETAO	0.633	0.633		0.629	0.624	
ETAD			0.380			0.357
JOS	0.658	0.640		0.616	0.599	
KTOS	0.101	0.109		0.120	0.128	
10KQOS	0.167	0.176		0.187	0.195	

RESULTS OF OVERLOAD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUM74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
NO BLOCKAGE CORRECTION APPLIED

VS KNOTS	8.558	8.558
Fn	0.094	0.094
FNVOL	0.220	0.220

MODEL OVERLOAD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KFD(15.0)	0.355	0.355		0.403	0.403	
JV	0.303	0.303		0.277	0.277	
KT	0.130	0.137		0.136	0.143	
10KQ	0.223	0.213		0.225	0.220	
JO	0.594	0.577		0.580	0.563	
10KQO	0.197	0.205		0.204	0.211	
WFTM	-0.964	-0.909		-1.092	-1.033	
THDF			-0.125			-0.151
ETAR	0.886	0.963		0.906	0.961	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

PE KW			20286			25871
PD KW	20629	39371	60000	27092	52908	80000
N RPM	127.9	127.9		139.6	139.6	
TH KN	1316.1	1390.2	4096.5	1644.8	1730.7	5106.2
Q KNm	1539.8	1469.4	4478.5	1852.8	1809.0	5470.8
FP KN			3865.2			5133.8
WFTS	-0.964	-0.909		-1.092	-1.033	
ETAO	0.623	0.616		0.617	0.610	
ETAD			0.338			0.323
JOS	0.594	0.577		0.580	0.563	
KTOS	0.130	0.137		0.136	0.143	
10KQOS	0.197	0.205		0.204	0.211	

RESULTS OF OVERLOAD EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUM74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
NO BLOCKAGE CORRECTION APPLIED

VS KNOTS	8.558	8.558
En	0.094	0.094
ENVOL	0.220	0.220

MODEL OVERLOAD DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KFD(15.0)	0.438	0.438		0.465	0.465	
JV	0.259	0.259		0.245	0.245	
KT	0.141	0.148		0.144	0.151	
10KQ	0.227	0.225		0.228	0.229	
JO	0.569	0.553		0.561	0.545	
10KQO	0.208	0.215		0.212	0.219	
WFTM	-1.200	-1.138		-1.294	-1.229	
THDF			-0.170			-0.186
ETAR	0.920	0.959		0.931	0.957	

PREDICTIONS OF SHIP PERFORMANCE WITH MODEL TEST PROPELLER

PE KW			31140			36152
PD KW	33512	66488	100000	39914	80086	120000
N RPM	149.6	149.6		158.2	158.2	
TH KN	1950.2	2046.9	6043.9	2237.6	2343.8	6925.1
Q KNm	2140.2	2122.9	6385.9	2409.0	2416.9	7242.8
EP KN			6330.5			7469.0
WFTS	-1.200	-1.138		-1.294	-1.229	
ETAO	0.613	0.604		0.608	0.600	
ETAD			0.311			0.301
JOS	0.569	0.553		0.561	0.545	
KTOS	0.141	0.148		0.144	0.151	
10KQOS	0.208	0.215		0.212	0.219	

RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
FORM FACTOR	2.385
SEA TEMPERATURE	15.0 deg C
TEST DATE	20-DEC-85

SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	FNVOL	CTVOL X100
4.00	211	102	0.044	10.872	0.301	4.420	0.103	2.850
5.00	395	154	0.055	10.338	0.249	4.249	0.129	2.740
6.00	643	208	0.066	9.809	0.088	3.995	0.155	2.576
7.00	961	267	0.077	9.357	-0.067	3.764	0.180	2.427
8.00	1412	343	0.088	9.114	-0.064	3.703	0.206	2.388
9.00	2076	448	0.099	9.082	0.113	3.825	0.232	2.466
10.00	2969	577	0.110	9.113	0.325	3.988	0.258	2.571
11.00	4071	719	0.121	9.117	0.488	4.108	0.283	2.649
12.00	5369	870	0.132	9.079	0.591	4.173	0.309	2.691
13.00	6846	1024	0.143	8.999	0.639	4.185	0.335	2.699
14.00	8604	1195	0.154	8.942	0.697	4.211	0.361	2.715
15.00	10939	1416	0.165	9.008	0.868	4.353	0.386	2.807
16.00	13896	1688	0.176	9.142	1.098	4.556	0.412	2.938
17.00	16807	1922	0.186	9.116	1.162	4.595	0.438	2.962
18.00	19979	2158	0.197	9.063	1.191	4.601	0.464	2.967
19.00	24070	2463	0.208	9.121	1.326	4.713	0.489	3.039
20.00	29263	2844	0.219	9.269	1.546	4.913	0.515	3.168
21.00	35579	3293	0.230	9.468	1.812	5.160	0.541	3.327
22.00	42805	3782	0.241	9.662	2.070	5.399	0.567	3.481
23.00	51007	4311	0.252	9.851	2.319	5.630	0.593	3.630
24.00	59310	4804	0.263	9.942	2.467	5.762	0.618	3.715
25.00	71668	5572	0.274	10.302	2.881	6.160	0.644	3.972
26.00	90054	6733	0.285	10.987	3.617	6.881	0.670	4.437

RESULTS OF SELF PROPULSION EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
FORM FACTOR	2.385
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS KNOTS	12.754	17.166
En	0.140	0.188
ENVOL	0.329	0.442

MODEL PROPULSION DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KED(15.0)	-0.217	-0.217		-0.199	-0.199	
JV	0.615	0.615		0.610	0.610	
KT	0.059	0.068		0.065	0.073	
10KQ	0.151	0.142		0.148	0.146	
JO	0.746	0.728		0.734	0.717	
10KQO	0.122	0.131		0.128	0.137	
WFTM	-0.213	-0.185		-0.204	-0.176	
THDF			0.072			0.077
ETAR	0.807	0.923		0.863	0.939	

PREDICTIONS FOR SHIP WITH MODEL TEST PROPELLER

PE KW			6463.			17292.
PD KW	5497.	5175.	15847.	13503.	13305.	40113.
N RPM	93.8	93.8		127.3	127.3	
TH KN	323.1	369.0	1061.1	651.0	734.8	2120.6
Q KNm	559.7	527.0	1613.8	1013.0	998.2	3009.3
WFTS	-0.213	-0.185		-0.204	-0.176	
ETAO	0.580	0.600		0.594	0.611	
ETAD			0.408			0.431
JOS	0.746	0.728		0.734	0.717	
KTOS	0.059	0.068		0.065	0.073	
10KQOS	0.122	0.131		0.128	0.137	

RESULTS OF SELF PROPULSION EXPERIMENTS

MODEL NUMBER 362
PROTECTION OF PROPELLERS
IN ICE

CENTER PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

WING PROPELLER NUMBER 74
MODIFIED STOCK DESIGN
P/D=0.847

SHIP LENGTH	224.25 m
DISPLACEMENT	68980 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
CENTER PROPELLER DIAMETER	6.83 m
WING PROPELLER DIAMETER	6.83 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
FORM FACTOR	2.385
SEA TEMPERATURE	15.0 deg C
TEST DATE	31-JAN-86

SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS KNOTS	19.202	21.408
En .	0.211	0.235
ENVOL	0.495	0.552

MODEL PROPULSION DATA

	CENTER	WINGS	TOTAL	CENTER	WINGS	TOTAL
KED(30.0)	-0.194	-0.194		-0.182	-0.182	
JV	0.607	0.607		0.594	0.594	
KT	0.068	0.076		0.073	0.081	
10KQ	0.148	0.148		0.149	0.153	
JO	0.728	0.711		0.719	0.701	
10KQO	0.131	0.140		0.136	0.146	
WETM	-0.200	-0.173		-0.210	-0.179	
THDF			0.092			0.096
ETAR	0.890	0.948		0.913	0.953	

PREDICTIONS FOR SHIP WITH MODEL TEST PROPELLER

PE KW			25025.			38439.
PD KW	19128.	19164.	57457.	28540.	29236.	87012.
N RPM	143.1	143.1		163.0	163.0	
TH KN	862.7	964.3	2791.2	1191.6	1333.7	3858.9
Q KNm	1276.2	1278.6	3833.5	1672.5	1713.3	5099.0
WFTS	-0.200	-0.173		-0.210	-0.179	
ETAO	0.601	0.615		0.609	0.622	
ETAD			0.436			0.442
JOS	0.728	0.711		0.719	0.701	
KTOS	0.068	0.076		0.073	0.081	
10KQOS	0.131	0.140		0.136	0.146	

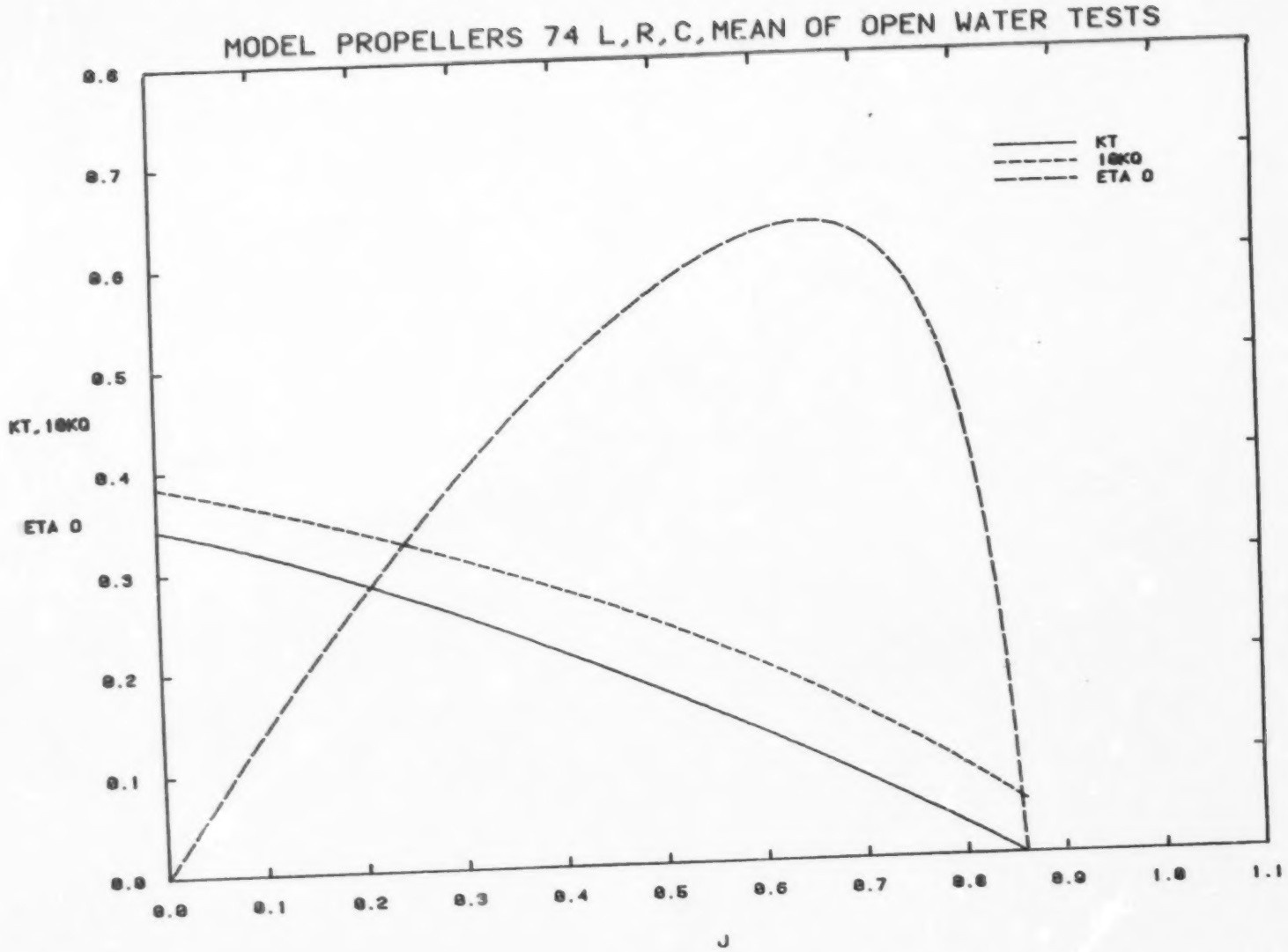

MODEL PROPELLERS 74 L,R,C,MEAN OF OPEN WATER TESTS
KT
10KQ
ETA 0
KT, 10KQ
ETA 0
J
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1

Figure 1

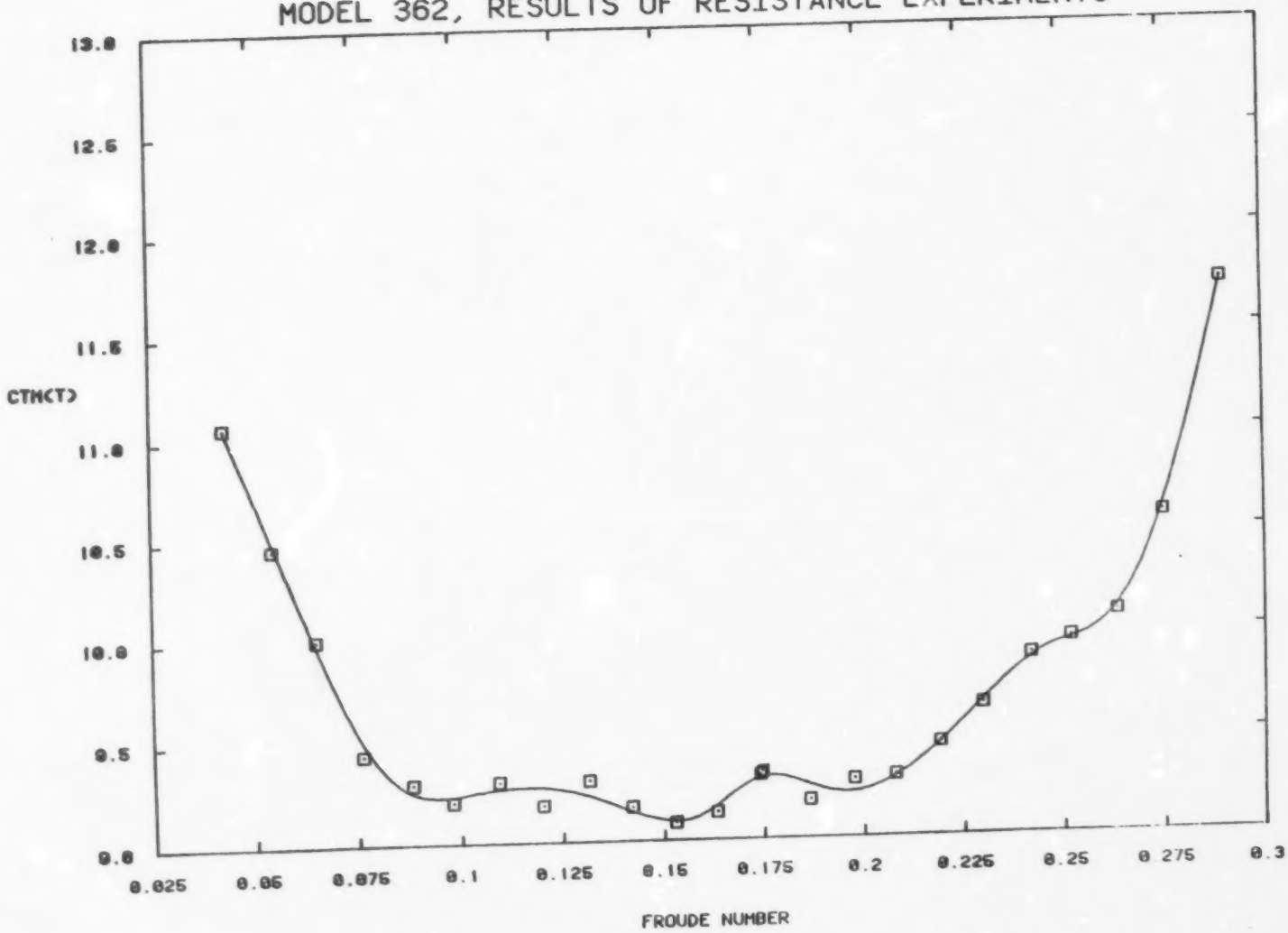

MODEL 362, RESULTS OF RESISTANCE EXPERIMENTS
13.0
12.5
12.0
11.5
CTM(CT)
11.0
10.5
10.0
9.5
9.0
0.025
0.05
0.075
0.1
0.125
0.15
0.175
0.2
0.225
0.25
0.275
0.3
FROUDE NUMBER

Figure 2

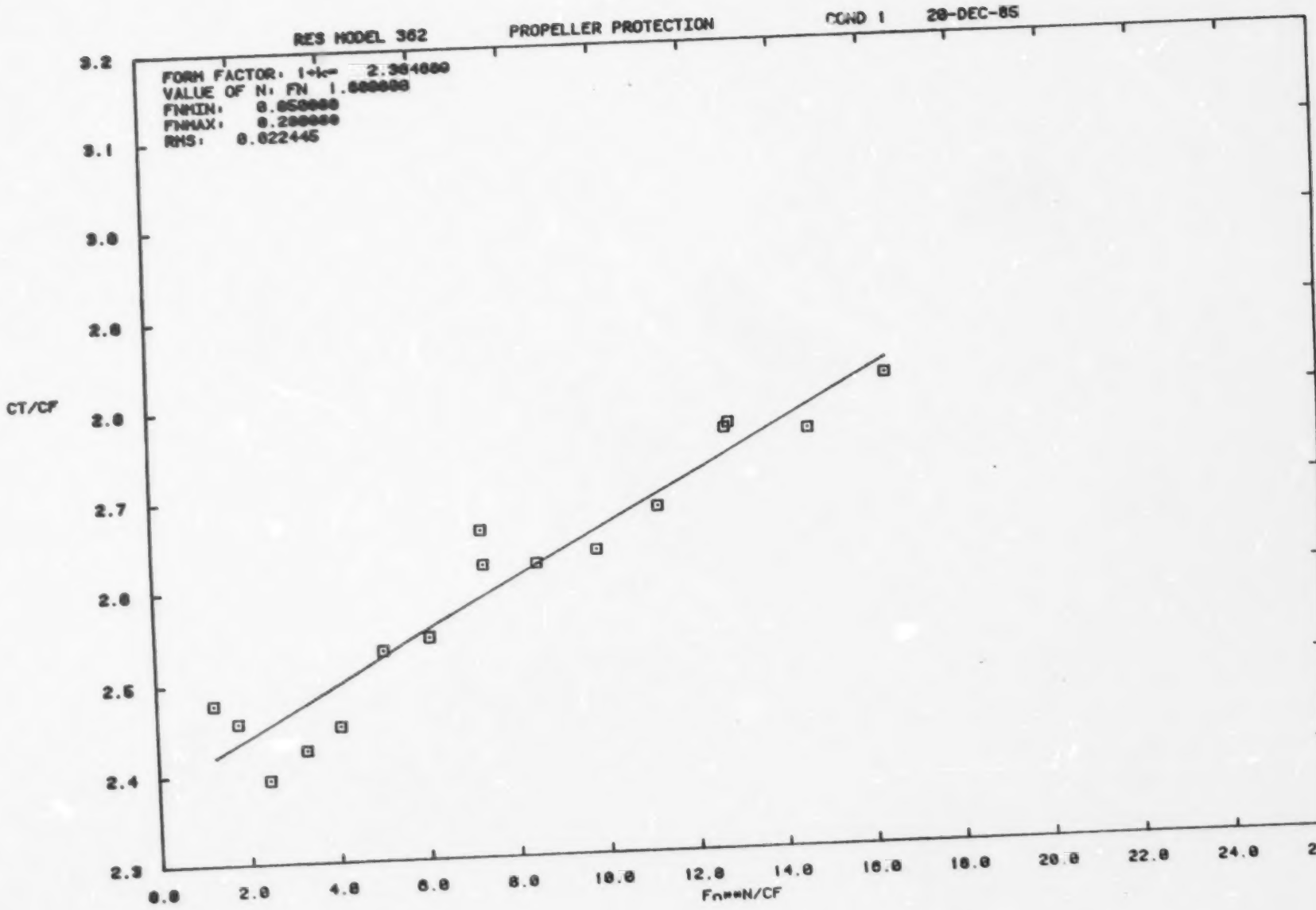

RES MODEL 362
PROPELLER PROTECTION
COND 1
20-DEC-85
FORM FACTOR: 1+k= 2.384689
VALUE OF N: FN 1.000000
FNMIN: 0.050000
FNMAX: 0.200000
RMS: 0.022445
CT/CF
3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
Fn**N/CF

Figure 3

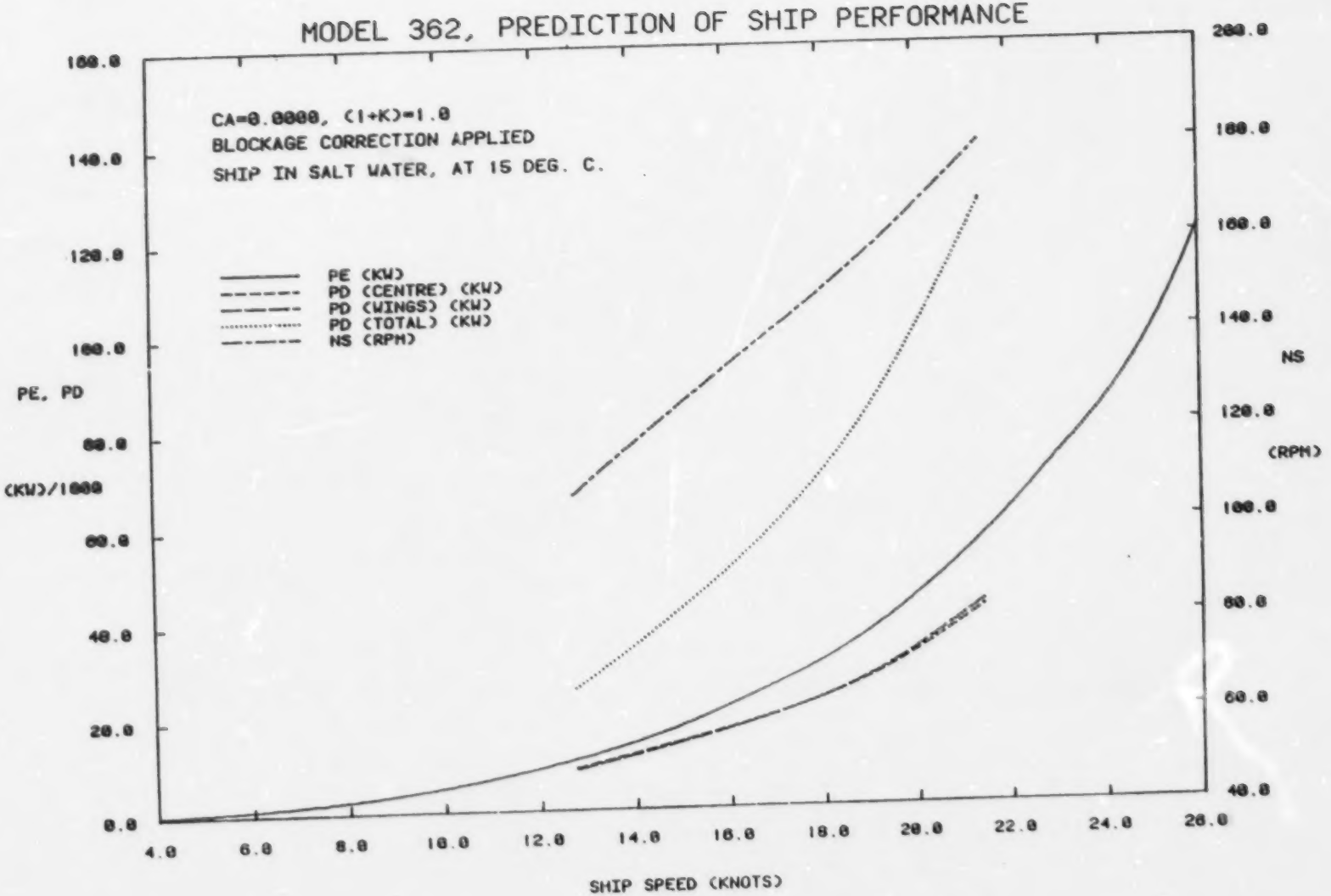

MODEL 362, PREDICTION OF SHIP PERFORMANCE
CA=0.0000, (1+K)=1.0
BLOCKAGE CORRECTION APPLIED
SHIP IN SALT WATER, AT 15 DEG. C.
PE (KW)
PD (CENTRE) (KW)
PD (WINGS) (KW)
PD (TOTAL) (KW)
NS (RPM)
PE, PD
(KW)/1000
NS
(RPM)
SHIP SPEED (KNOTS)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0

Figure 4

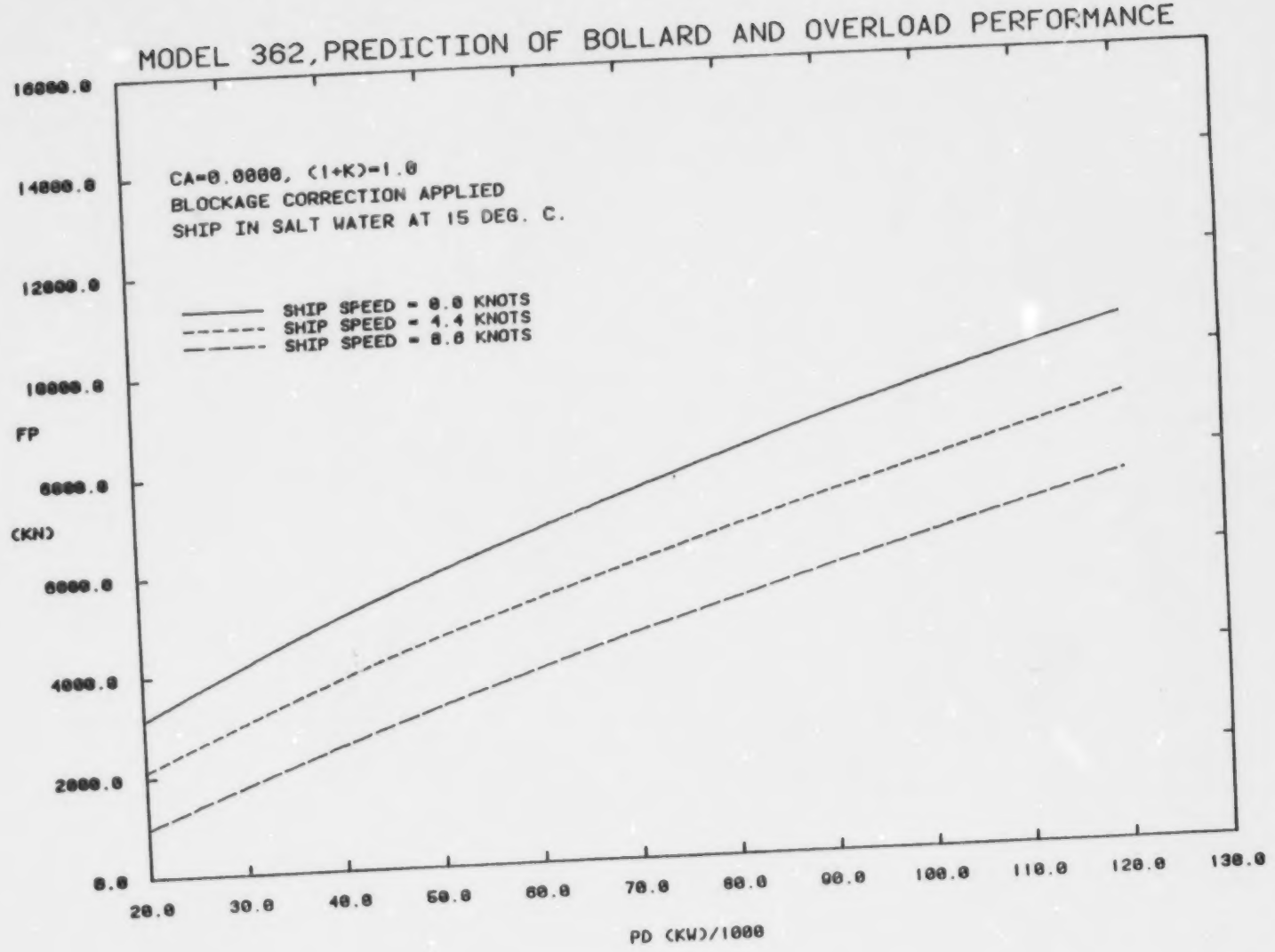

MODEL 362,PREDICTION OF BOLLARD AND OVERLOAD PERFORMANCE
CA=0.0000, (1+K)=1.0
BLOCKAGE CORRECTION APPLIED
SHIP IN SALT WATER AT 15 DEG. C.
SHIP SPEED = 0.0 KNOTS
SHIP SPEED = 4.4 KNOTS
SHIP SPEED = 8.8 KNOTS
FP
(KN)
16000.0
14000.0
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
PD (KW)/1000

Figure 5

WAKE SURVEY EXPERIMENTS

CENTRE SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	8.0 knots
FRACTIONAL RADIUS	0.324

THETA	VX/V	VT/V	VR/V
0.000	0.608	0.000	0.075
5.000	0.610	-0.008	0.074
10.000	0.611	-0.018	0.072
15.000	0.610	-0.029	0.068
20.000	0.610	-0.041	0.064
25.000	0.667	-0.050	0.060
30.000	0.863	-0.058	0.055
35.000	0.853	-0.065	0.050
40.000	0.632	-0.070	0.046
45.000	0.668	-0.075	0.044
50.000	0.744	-0.078	0.043
55.000	0.821	-0.081	0.044
60.000	0.877	-0.084	0.048
65.000	0.910	-0.087	0.053
70.000	0.931	-0.089	0.056
75.000	0.944	-0.091	0.058
80.000	0.951	-0.092	0.059
85.000	0.955	-0.093	0.059
90.000	0.956	-0.094	0.060
95.000	0.957	-0.094	0.060
100.000	0.957	-0.093	0.061
105.000	0.956	-0.092	0.061
110.000	0.955	-0.091	0.061
115.000	0.953	-0.089	0.062
120.000	0.951	-0.088	0.062
125.000	0.948	-0.086	0.062
130.000	0.944	-0.085	0.062
135.000	0.941	-0.084	0.063
140.000	0.937	-0.083	0.063
145.000	0.933	-0.081	0.063
150.000	0.929	-0.076	0.063
155.000	0.925	-0.068	0.063
160.000	0.921	-0.055	0.063
165.000	0.917	-0.038	0.063
170.000	0.913	-0.021	0.063
175.000	0.910	-0.008	0.063
180.000	0.907	0.000	0.063

WAKE SURVEY EXPERIMENTS

CENTRE SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	8.0 knots
FRACTIONAL RADIUS	0.512

THETA	VX/V	VT/V	VR/V
0.000	0.646	0.000	0.060
5.000	0.650	-0.007	0.055
10.000	0.654	-0.016	0.050
15.000	0.660	-0.025	0.045
20.000	0.668	-0.035	0.040
25.000	0.680	-0.045	0.035
30.000	0.695	-0.053	0.031
35.000	0.714	-0.060	0.027
40.000	0.734	-0.066	0.023
45.000	0.757	-0.069	0.021
50.000	0.782	-0.072	0.020
55.000	0.808	-0.073	0.021
60.000	0.834	-0.074	0.023
65.000	0.858	-0.074	0.027
70.000	0.879	-0.074	0.031
75.000	0.897	-0.073	0.036
80.000	0.910	-0.073	0.041
85.000	0.920	-0.072	0.047
90.000	0.926	-0.072	0.052
95.000	0.930	-0.071	0.058
100.000	0.933	-0.071	0.063
105.000	0.934	-0.071	0.068
110.000	0.935	-0.071	0.072
115.000	0.936	-0.071	0.076
120.000	0.937	-0.072	0.079
125.000	0.937	-0.072	0.081
130.000	0.938	-0.072	0.082
135.000	0.939	-0.070	0.083
140.000	0.940	-0.068	0.083
145.000	0.941	-0.064	0.083
150.000	0.941	-0.059	0.083
155.000	0.942	-0.052	0.083
160.000	0.942	-0.043	0.082
165.000	0.941	-0.033	0.082
170.000	0.940	-0.023	0.082
175.000	0.939	-0.011	0.080
180.000	0.939	0.000	0.079

WAKE SURVEY EXPERIMENTS

CENTRE SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	8.0 knots
FRACTIONAL RADIUS	0.701

THETA	VX/V	VT/V	VR/V
0.000	0.534	0.000	-0.006
5.000	0.548	-0.020	-0.010
10.000	0.564	-0.051	-0.014
15.000	0.582	-0.078	-0.022
20.000	0.602	-0.101	-0.031
25.000	0.666	-0.116	-0.038
30.000	0.802	-0.125	-0.043
35.000	0.856	-0.128	-0.047
40.000	0.825	-0.128	-0.051
45.000	0.754	-0.125	-0.055
50.000	0.700	-0.120	-0.059
55.000	0.798	-0.114	-0.063
60.000	0.889	-0.107	-0.064
65.000	0.909	-0.101	-0.061
70.000	0.916	-0.095	-0.056
75.000	0.920	-0.090	-0.049
80.000	0.923	-0.085	-0.042
85.000	0.925	-0.083	-0.035
90.000	0.927	-0.082	-0.027
95.000	0.928	-0.082	-0.020
100.000	0.929	-0.084	-0.013
105.000	0.930	-0.087	-0.007
110.000	0.929	-0.090	-0.002
115.000	0.928	-0.092	0.002
120.000	0.926	-0.093	0.004
125.000	0.923	-0.091	0.006
130.000	0.919	-0.088	0.007
135.000	0.915	-0.085	0.008
140.000	0.912	-0.083	0.008
145.000	0.908	-0.084	0.007
150.000	0.905	-0.085	0.007
155.000	0.904	-0.084	0.006
160.000	0.903	-0.076	0.005
165.000	0.903	-0.058	0.004
170.000	0.904	-0.036	0.004
175.000	0.906	-0.014	0.003
180.000	0.907	0.000	0.002

WAKE SURVEY EXPERIMENTS

CENTRE SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	8.0 knots
FRACTIONAL RADIUS	0.890

THETA	VX/V	VT/V	VR/V
0.000	0.540	0.000	-0.005
5.000	0.554	-0.004	-0.007
10.000	0.566	-0.007	-0.008
15.000	0.577	-0.011	-0.010
20.000	0.583	-0.014	-0.012
25.000	0.574	-0.018	-0.014
30.000	0.548	-0.021	-0.017
35.000	0.526	-0.023	-0.019
40.000	0.533	-0.025	-0.022
45.000	0.589	-0.027	-0.025
50.000	0.683	-0.029	-0.028
55.000	0.775	-0.030	-0.030
60.000	0.829	-0.031	-0.031
65.000	0.852	-0.032	-0.032
70.000	0.865	-0.033	-0.031
75.000	0.877	-0.035	-0.030
80.000	0.887	-0.036	-0.027
85.000	0.896	-0.037	-0.022
90.000	0.904	-0.038	-0.017
95.000	0.911	-0.038	-0.010
100.000	0.918	-0.039	-0.002
105.000	0.924	-0.039	0.008
110.000	0.930	-0.038	0.019
115.000	0.935	-0.037	0.032
120.000	0.940	-0.036	0.044
125.000	0.944	-0.034	0.054
130.000	0.948	-0.032	0.060
135.000	0.951	-0.029	0.060
140.000	0.953	-0.026	0.054
145.000	0.955	-0.023	0.046
150.000	0.956	-0.020	0.040
155.000	0.957	-0.017	0.037
160.000	0.956	-0.014	0.035
165.000	0.955	-0.010	0.032
170.000	0.953	-0.007	0.030
175.000	0.952	-0.004	0.030
180.000	0.952	0.000	0.030

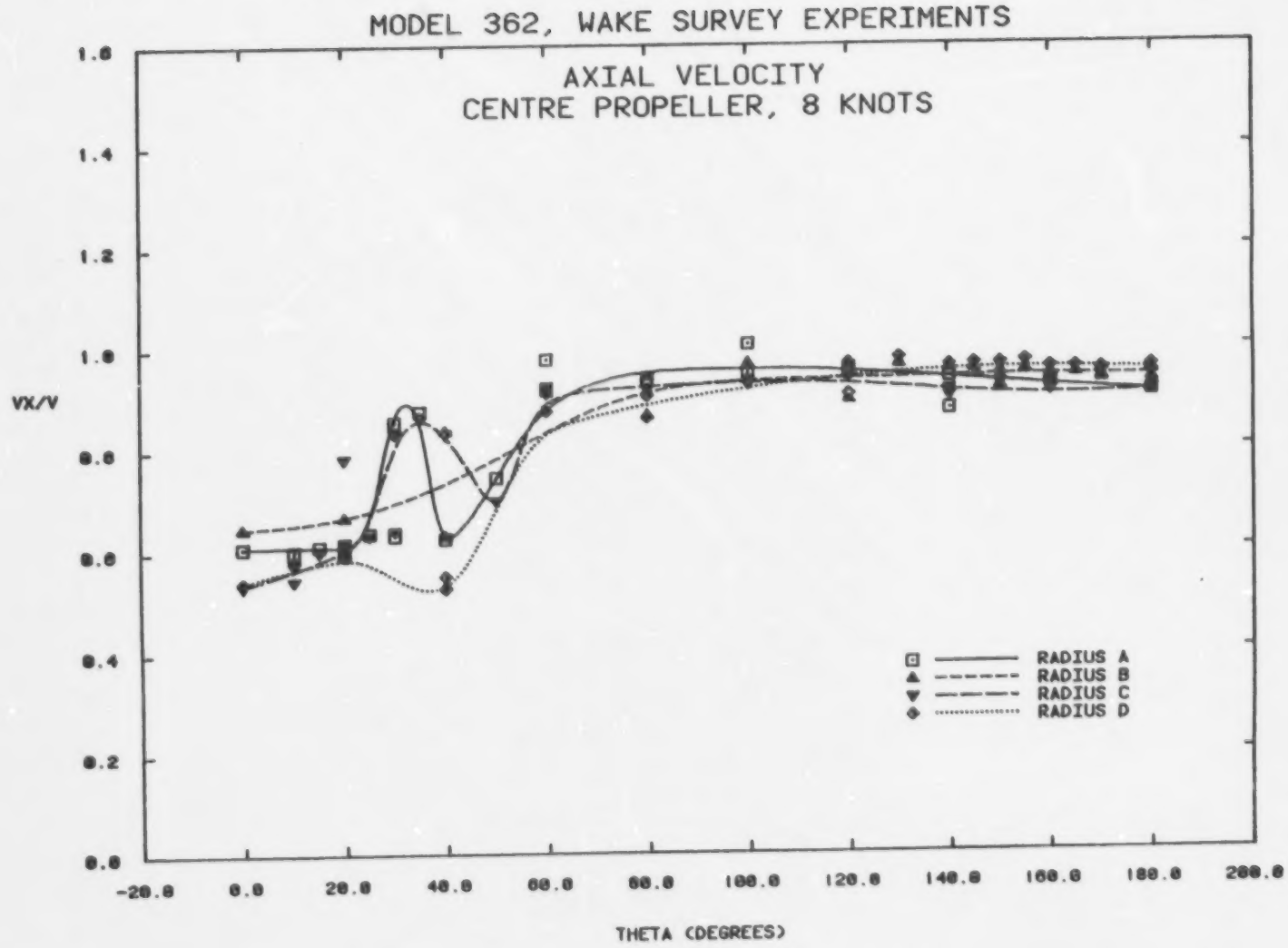

MODEL 362, WAKE SURVEY EXPERIMENTS
AXIAL VELOCITY
CENTRE PROPELLER, 8 KNOTS
VX/V
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 6

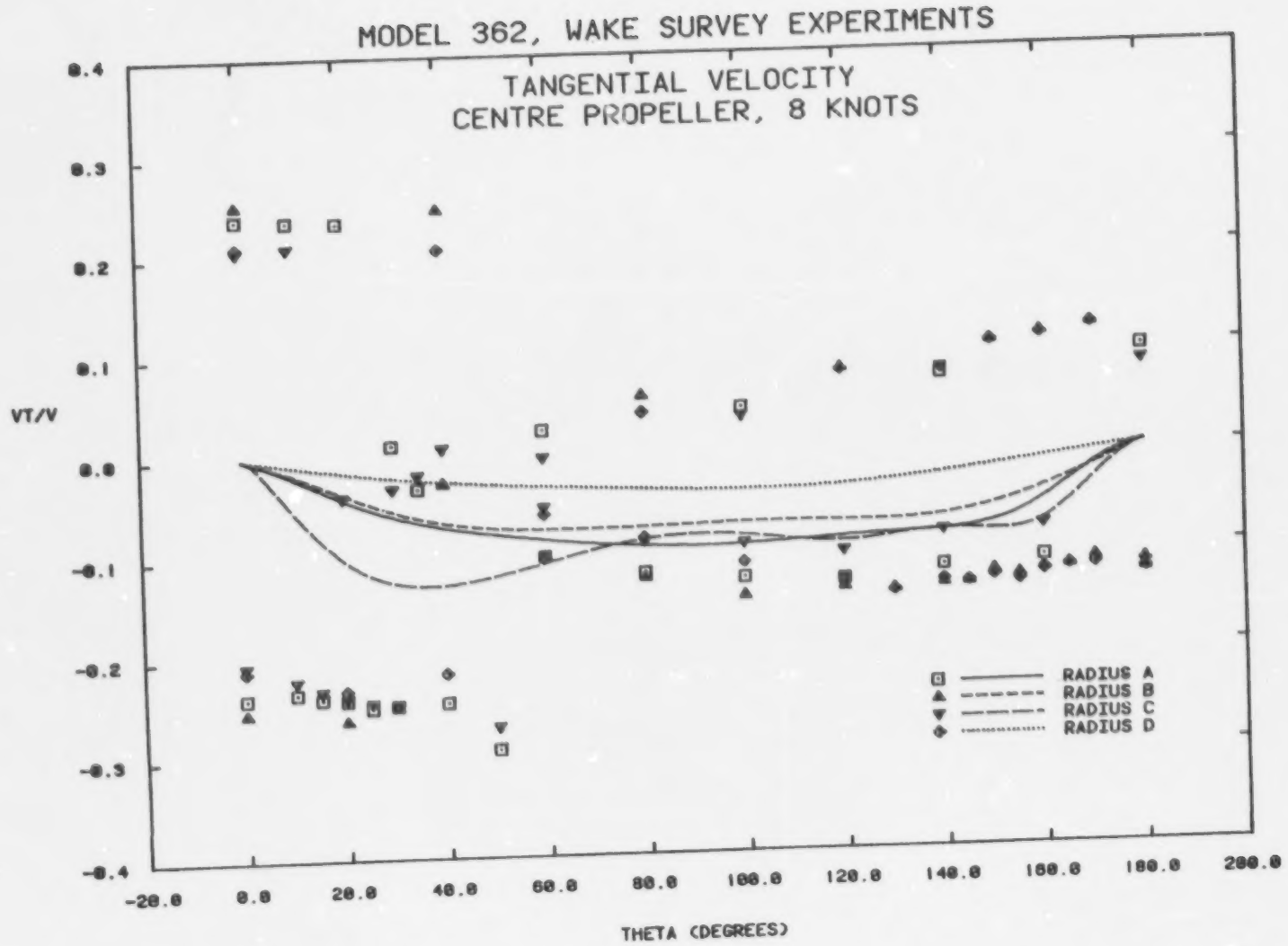

MODEL 362, WAKE SURVEY EXPERIMENTS
TANGENTIAL VELOCITY
CENTRE PROPELLER, 8 KNOTS
VT/V
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 7

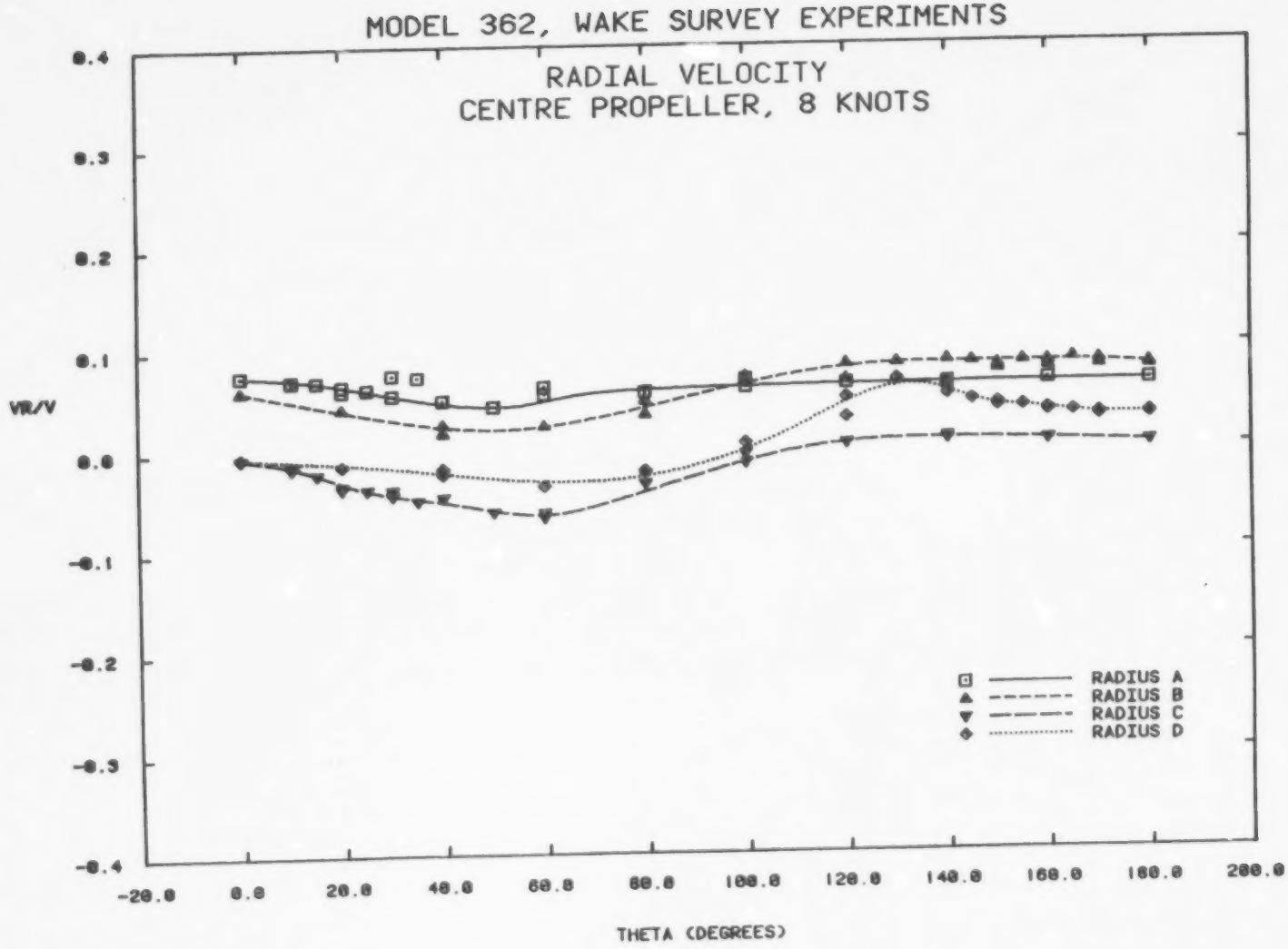

MODEL 362, WAKE SURVEY EXPERIMENTS
RADIAL VELOCITY
CENTRE PROPELLER, 8 KNOTS
VR/V
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 8

WAKE SURVEY EXPERIMENTS

CENTRE SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25	m
DISPLACEMENT	68991	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
PROPELLER DIAMETER	6.83	m
SHIP SPEED	16.0	knots
FRACTIONAL RADIUS	0.324	

THETA	VX/V	VT/V	VR/V
0.000	0.860	0.000	0.100
5.000	0.866	-0.003	0.098
10.000	0.871	-0.009	0.096
15.000	0.876	-0.014	0.092
20.000	0.881	-0.020	0.087
25.000	0.894	-0.027	0.083
30.000	0.911	-0.034	0.080
35.000	0.921	-0.042	0.076
40.000	0.903	-0.051	0.071
45.000	0.867	-0.060	0.064
50.000	0.863	-0.069	0.057
55.000	0.883	-0.076	0.052
60.000	0.907	-0.082	0.050
65.000	0.923	-0.087	0.049
70.000	0.935	-0.091	0.049
75.000	0.943	-0.093	0.050
80.000	0.950	-0.094	0.051
85.000	0.955	-0.094	0.053
90.000	0.960	-0.094	0.055
95.000	0.964	-0.094	0.057
100.000	0.969	-0.094	0.059
105.000	0.973	-0.093	0.062
110.000	0.978	-0.092	0.064
115.000	0.982	-0.091	0.065
120.000	0.987	-0.090	0.066
125.000	0.991	-0.088	0.066
130.000	0.995	-0.086	0.067
135.000	0.999	-0.084	0.067
140.000	1.003	-0.083	0.066
145.000	1.007	-0.081	0.066
150.000	1.011	-0.077	0.066
155.000	1.015	-0.070	0.067
160.000	1.019	-0.057	0.067
165.000	1.022	-0.041	0.067
170.000	1.026	-0.023	0.068
175.000	1.029	-0.006	0.069
180.000	1.033	0.000	0.069

WAKE SURVEY EXPERIMENTS

CENTRE SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	16.0 knots
FRACTIONAL RADIUS	0.512

THETA	VX/V	VT/V	VR/V
0.000	0.875	0.000	0.073
5.000	0.876	-0.001	0.068
10.000	0.879	-0.002	0.063
15.000	0.883	-0.003	0.058
20.000	0.887	-0.006	0.054
25.000	0.891	-0.009	0.049
30.000	0.896	-0.014	0.045
35.000	0.899	-0.020	0.041
40.000	0.901	-0.027	0.036
45.000	0.841	-0.035	0.030
50.000	0.843	-0.043	0.023
55.000	0.867	-0.052	0.017
60.000	0.885	-0.060	0.016
65.000	0.900	-0.069	0.017
70.000	0.913	-0.078	0.021
75.000	0.924	-0.087	0.027
80.000	0.935	-0.095	0.037
85.000	0.945	-0.101	0.045
90.000	0.955	-0.106	0.052
95.000	0.964	-0.110	0.058
100.000	0.973	-0.111	0.063
105.000	0.983	-0.110	0.068
110.000	0.993	-0.108	0.072
115.000	1.004	-0.104	0.076
120.000	1.014	-0.099	0.080
125.000	1.023	-0.093	0.083
130.000	1.031	-0.087	0.085
135.000	1.037	-0.080	0.086
140.000	1.040	-0.072	0.086
145.000	1.040	-0.065	0.085
150.000	1.040	-0.057	0.085
155.000	1.040	-0.047	0.085
160.000	1.041	-0.037	0.084
165.000	1.043	-0.027	0.084
170.000	1.044	-0.015	0.083
175.000	1.043	-0.004	0.082
180.000	1.042	0.000	0.081

WAKE SURVEY EXPERIMENTS

CENTRE SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	16.0 knots
FRACTIONAL RADIUS	0.701

THETA	VX/V	VT/V	VR/V
0.000	0.759	0.000	-0.015
5.000	0.765	-0.007	-0.021
10.000	0.771	-0.018	-0.028
15.000	0.779	-0.030	-0.034
20.000	0.796	-0.043	-0.039
25.000	0.828	-0.053	-0.043
30.000	0.865	-0.059	-0.045
35.000	0.890	-0.063	-0.049
40.000	0.901	-0.066	-0.058
45.000	0.904	-0.067	-0.070
50.000	0.906	-0.068	-0.074
55.000	0.910	-0.068	-0.070
60.000	0.914	-0.068	-0.064
65.000	0.920	-0.068	-0.057
70.000	0.927	-0.069	-0.050
75.000	0.936	-0.070	-0.043
80.000	0.946	-0.071	-0.036
85.000	0.956	-0.073	-0.029
90.000	0.967	-0.074	-0.023
95.000	0.977	-0.074	-0.017
100.000	0.986	-0.074	-0.011
105.000	0.994	-0.072	-0.007
110.000	1.000	-0.069	-0.003
115.000	1.003	-0.064	0.000
120.000	1.005	-0.058	0.002
125.000	1.006	-0.051	0.004
130.000	1.006	-0.043	0.004
135.000	1.005	-0.035	0.005
140.000	1.004	-0.027	0.004
145.000	1.004	-0.020	0.004
150.000	1.004	-0.014	0.004
155.000	1.006	-0.010	0.004
160.000	1.010	-0.006	0.004
165.000	1.014	-0.004	0.004
170.000	1.019	-0.002	0.004
175.000	1.024	-0.001	0.004
180.000	1.030	0.000	0.004

WAKE SURVEY EXPERIMENTS

CENTRE SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25	m
DISPLACEMENT	68991	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
PROPELLER DIAMETER	6.83	m
SHIP SPEED	16.0	knots
FRACTIONAL RADIUS	0.890	

THETA	VX/V	VT/V	VR/V
0.000	0.795	0.000	-0.007
5.000	0.786	-0.002	-0.008
10.000	0.777	-0.010	-0.009
15.000	0.770	-0.018	-0.011
20.000	0.766	-0.025	-0.012
25.000	0.764	-0.031	-0.013
30.000	0.766	-0.037	-0.015
35.000	0.773	-0.043	-0.017
40.000	0.786	-0.048	-0.019
45.000	0.807	-0.053	-0.020
50.000	0.835	-0.057	-0.022
55.000	0.866	-0.061	-0.023
60.000	0.898	-0.065	-0.023
65.000	0.928	-0.069	-0.023
70.000	0.954	-0.073	-0.022
75.000	0.972	-0.077	-0.020
80.000	0.985	-0.081	-0.018
85.000	0.994	-0.084	-0.013
90.000	1.001	-0.086	-0.008
95.000	1.006	-0.087	-0.001
100.000	1.012	-0.086	0.007
105.000	1.021	-0.083	0.017
110.000	1.033	-0.077	0.029
115.000	1.050	-0.069	0.041
120.000	1.069	-0.059	0.051
125.000	1.089	-0.050	0.055
130.000	1.105	-0.042	0.057
135.000	1.117	-0.037	0.057
140.000	1.121	-0.035	0.055
145.000	1.121	-0.036	0.053
150.000	1.120	-0.036	0.051
155.000	1.120	-0.036	0.047
160.000	1.121	-0.034	0.044
165.000	1.121	-0.032	0.042
170.000	1.121	-0.024	0.042
175.000	1.122	-0.013	0.041
180.000	1.122	-0.006	0.042

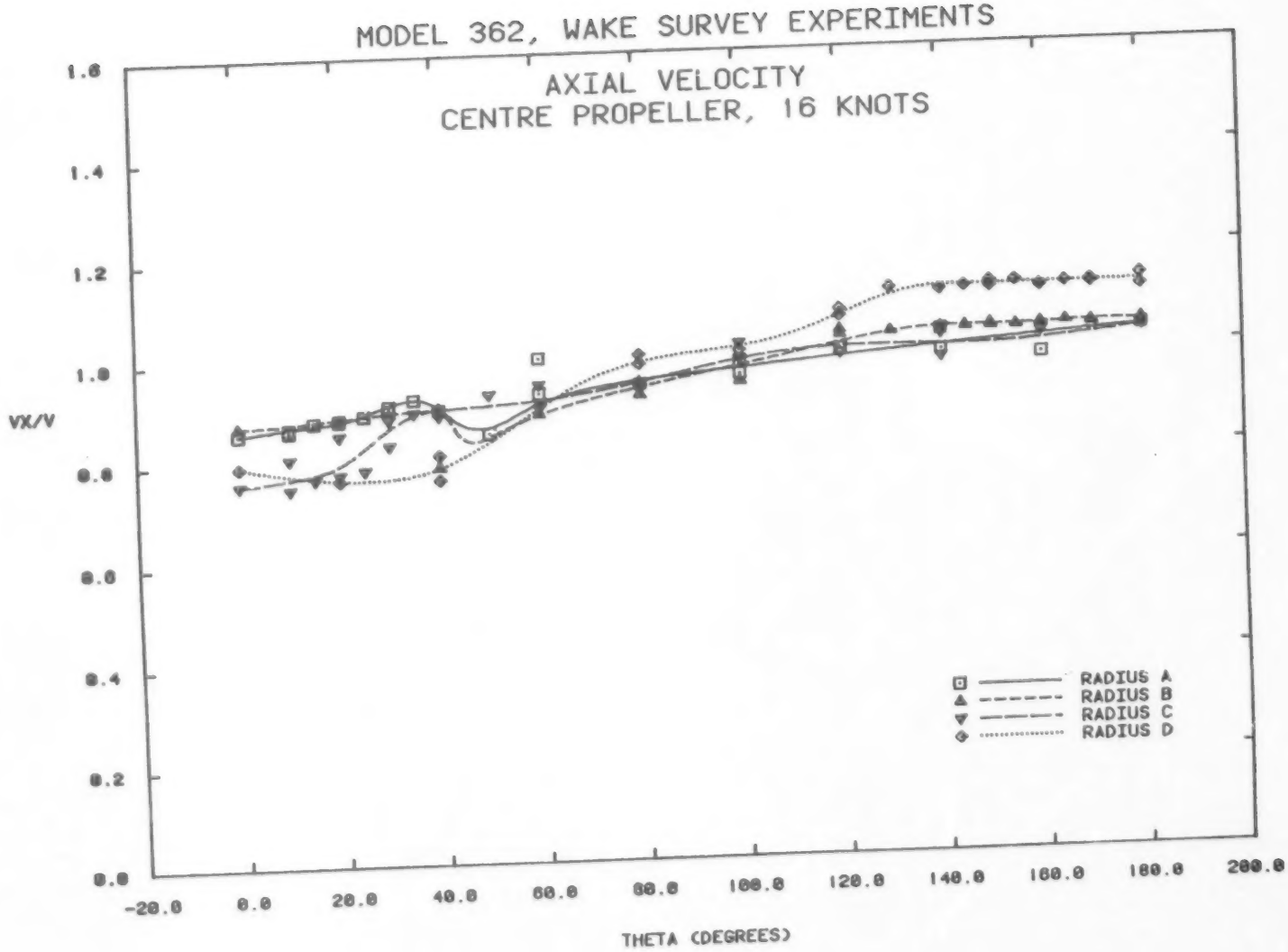

MODEL 362, WAKE SURVEY EXPERIMENTS
AXIAL VELOCITY
CENTRE PROPELLER, 16 KNOTS
VX/V
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 9

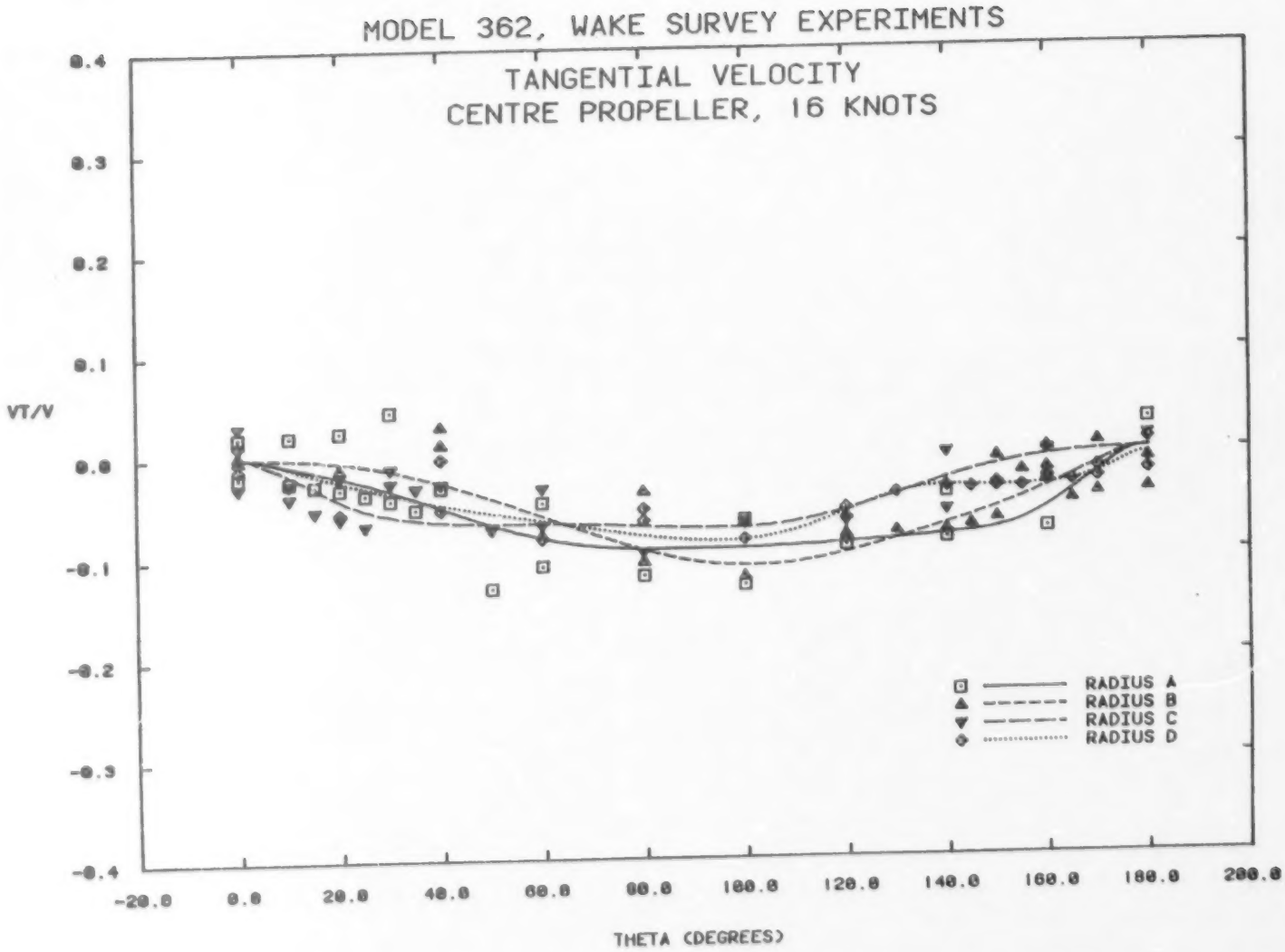

MODEL 362, WAKE SURVEY EXPERIMENTS
TANGENTIAL VELOCITY
CENTRE PROPELLER, 16 KNOTS
VT/V
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 10

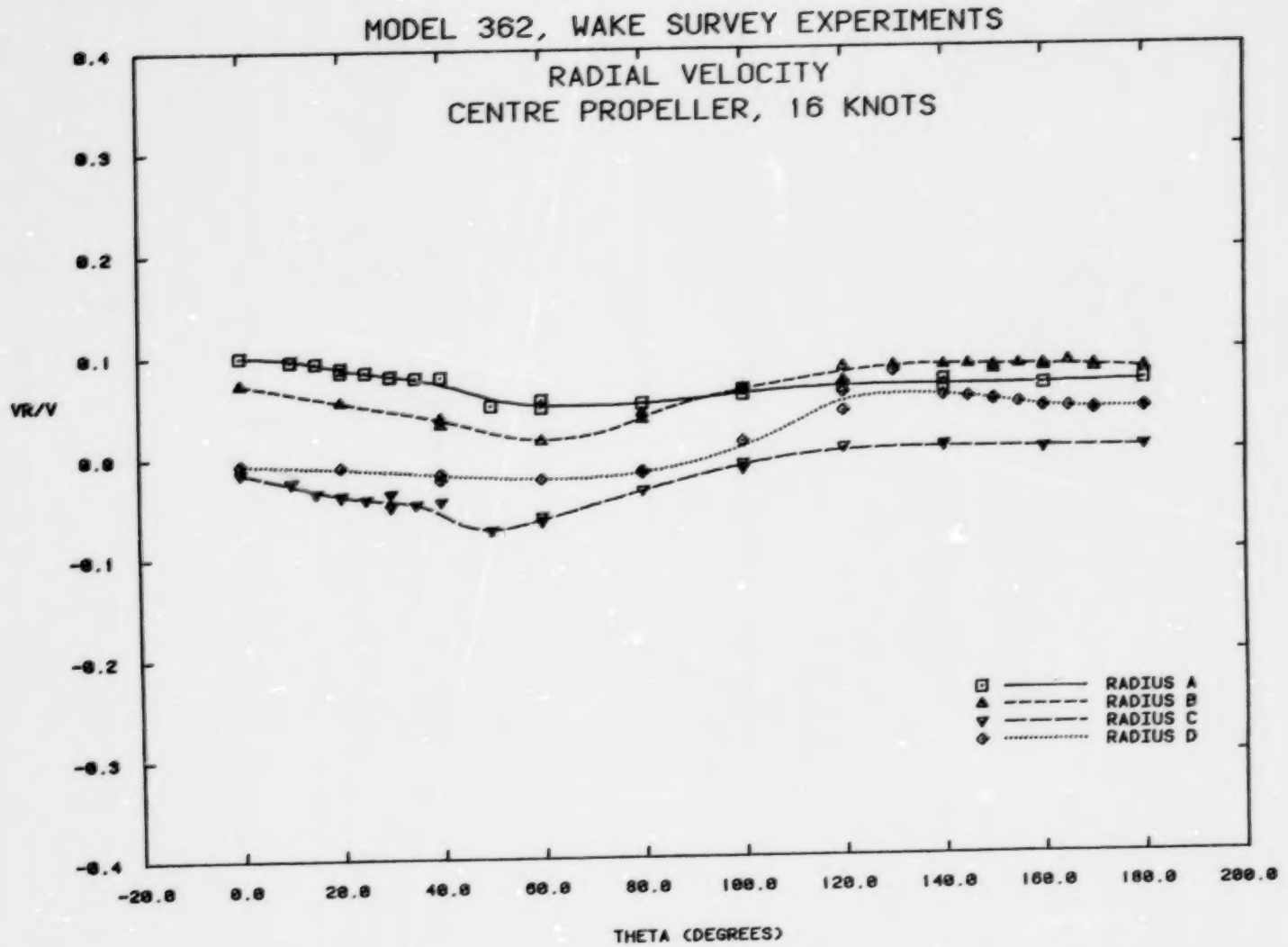

MODEL 362, WAKE SURVEY EXPERIMENTS
RADIAL VELOCITY
CENTRE PROPELLER, 16 KNOTS
VR/V
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 11

WAKE SURVEY EXPERIMENTS

PORT SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	8.0 knots
FRACTIONAL RADIUS	0.324

THETA	VX/V	VT/V	VR/V
0.000	0.549	0.216	0.076
10.000	0.549	0.216	0.074
20.000	0.561	0.221	0.064
30.000	0.580	0.227	0.056
40.000	0.599	0.238	0.046
50.000	0.645	0.241	0.040
60.000	0.727	0.226	0.042
70.000	0.813	0.202	0.047
80.000	0.873	0.176	0.050
90.000	0.910	0.152	0.051
100.000	0.930	0.132	0.052
110.000	0.939	0.119	0.052
120.000	0.943	0.113	0.052
130.000	0.942	0.112	0.053
140.000	0.939	0.113	0.054
150.000	0.934	0.114	0.056
160.000	0.927	0.111	0.058
170.000	0.916	0.106	0.060
180.000	0.904	0.098	0.063
190.000	0.895	0.090	0.065
200.000	0.888	0.081	0.066
210.000	0.908	0.072	0.067
220.000	0.954	0.064	0.067
230.000	0.983	0.055	0.066
240.000	0.982	0.046	0.063
250.000	0.980	0.038	0.060
260.000	0.977	0.031	0.056
270.000	0.972	0.025	0.055
280.000	0.967	0.021	0.055
290.000	0.959	0.020	0.057
300.000	0.946	0.015	0.058
310.000	0.896	-0.001	0.055
320.000	0.450	0.140	0.042
330.000	0.569	0.226	0.050
340.000	0.552	0.218	0.062
350.000	0.550	0.216	0.069
360.000	0.549	0.216	0.076

WAKE SURVEY EXPERIMENTS

PORT SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	8.0 knots
FRACTIONAL RADIUS	0.512

THETA	VX/V	VT/V	VR/V
0.000	0.507	-0.199	0.055
10.000	0.523	-0.192	0.040
20.000	0.526	-0.186	0.028
30.000	0.478	-0.178	0.019
40.000	0.444	-0.140	0.015
50.000	0.498	-0.005	0.015
60.000	0.674	0.045	0.019
70.000	0.852	0.031	0.025
80.000	0.925	0.013	0.033
90.000	0.956	0.002	0.041
100.000	0.969	-0.004	0.049
110.000	0.973	-0.008	0.056
120.000	0.975	-0.014	0.060
130.000	0.978	-0.021	0.065
140.000	0.980	-0.028	0.071
150.000	0.983	-0.036	0.077
160.000	0.987	-0.041	0.079
170.000	0.990	-0.046	0.083
180.000	0.992	-0.055	0.091
190.000	0.993	-0.062	0.099
200.000	0.993	-0.071	0.104
210.000	0.994	-0.082	0.107
220.000	0.983	-0.089	0.102
230.000	0.922	-0.091	0.085
240.000	0.880	-0.091	0.068
250.000	0.880	-0.090	0.057
260.000	0.894	-0.087	0.050
270.000	0.893	-0.074	0.042
280.000	0.852	-0.057	0.033
290.000	0.779	-0.148	0.024
300.000	0.692	-0.272	0.016
310.000	0.614	-0.258	0.012
320.000	0.561	-0.236	0.014
330.000	0.529	-0.221	0.020
340.000	0.513	-0.213	0.029
350.000	0.508	-0.206	0.041
360.000	0.507	-0.199	0.055

WAKE SURVEY EXPERIMENTS

PORT SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	8.0 knots
FRACTIONAL RADIUS	0.701

THETA	VX/V	VT/V	VR/V
0.000	0.426	0.198	-0.001
10.000	0.501	0.199	-0.015
20.000	0.520	0.201	-0.027
30.000	0.553	0.214	-0.030
40.000	0.558	0.215	-0.038
50.000	0.561	0.221	-0.046
60.000	0.609	0.251	-0.043
70.000	0.682	0.277	-0.034
80.000	0.758	0.272	-0.027
90.000	0.826	0.212	-0.021
100.000	0.880	0.084	-0.017
110.000	0.916	0.080	-0.013
120.000	0.931	0.079	-0.010
130.000	0.931	0.081	-0.006
140.000	0.923	0.083	-0.003
150.000	0.915	0.084	0.001
160.000	0.910	0.084	0.005
170.000	0.909	0.083	0.009
180.000	0.907	0.081	0.012
190.000	0.902	0.076	0.015
200.000	0.893	0.066	0.015
210.000	0.880	0.053	0.014
220.000	0.868	0.044	0.011
230.000	0.860	0.039	0.006
240.000	0.859	0.041	-0.002
250.000	0.867	0.045	-0.013
260.000	0.884	0.047	-0.027
270.000	0.912	0.046	-0.044
280.000	0.945	0.039	-0.063
290.000	0.958	0.017	-0.076
300.000	0.920	-0.024	-0.078
310.000	0.780	-0.034	-0.063
320.000	0.592	0.213	-0.039
330.000	0.534	0.213	-0.030
340.000	0.501	0.197	-0.019
350.000	0.462	0.195	-0.008
360.000	0.425	0.195	-0.001

WAKE SURVEY EXPERIMENTS

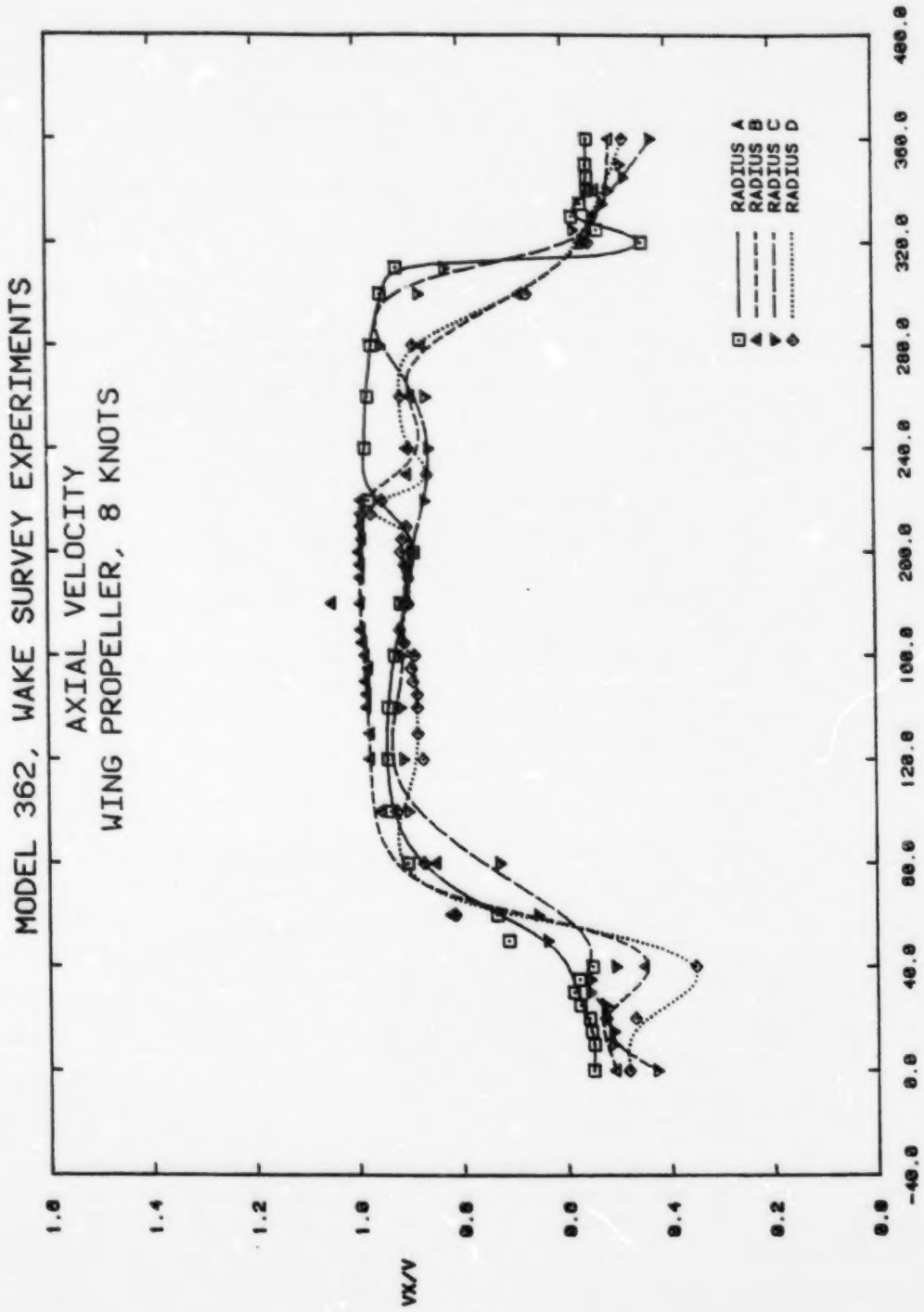
PORT SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25 m
DISPLACEMENT	68991 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
PROPELLER DIAMETER	6.83 m
SHIP SPEED	8.0 knots
FRACTIONAL RADIUS	0.890

THETA	VX/V	VT/V	VR/V
0.000	0.480	-0.188	0.002
10.000	0.481	-0.182	-0.003
20.000	0.444	-0.175	-0.009
30.000	0.372	-0.165	-0.016
40.000	0.356	-0.119	-0.023
50.000	0.468	-0.008	-0.028
60.000	0.701	0.028	-0.028
70.000	0.858	0.027	-0.023
80.000	0.911	0.015	-0.012
90.000	0.922	-0.006	0.002
100.000	0.913	-0.030	0.016
110.000	0.897	-0.050	0.025
120.000	0.887	-0.062	0.029
130.000	0.883	-0.068	0.029
140.000	0.885	-0.070	0.029
150.000	0.887	-0.070	0.028
160.000	0.896	-0.077	0.026
170.000	0.914	-0.093	0.024
180.000	0.900	-0.084	0.021
190.000	0.905	-0.078	0.027
200.000	0.904	-0.085	0.054
210.000	0.920	-0.078	0.067
220.000	0.951	-0.048	0.052
230.000	0.863	-0.049	0.022
240.000	0.890	-0.061	-0.001
250.000	0.910	-0.068	-0.014
260.000	0.914	-0.079	-0.020
270.000	0.910	-0.100	-0.023
280.000	0.879	-0.131	-0.025
290.000	0.795	-0.164	-0.026
300.000	0.689	-0.192	-0.025
310.000	0.613	-0.209	-0.024
320.000	0.569	-0.216	-0.020
330.000	0.540	-0.215	-0.016
340.000	0.518	-0.209	-0.010
350.000	0.498	-0.199	-0.004
360.000	0.480	-0.188	0.002


MODEL 362, WAKE SURVEY EXPERIMENTS
AXIAL VELOCITY
WING PROPELLER, 8 KNOTS
VX/V
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-40.0
0.0
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0

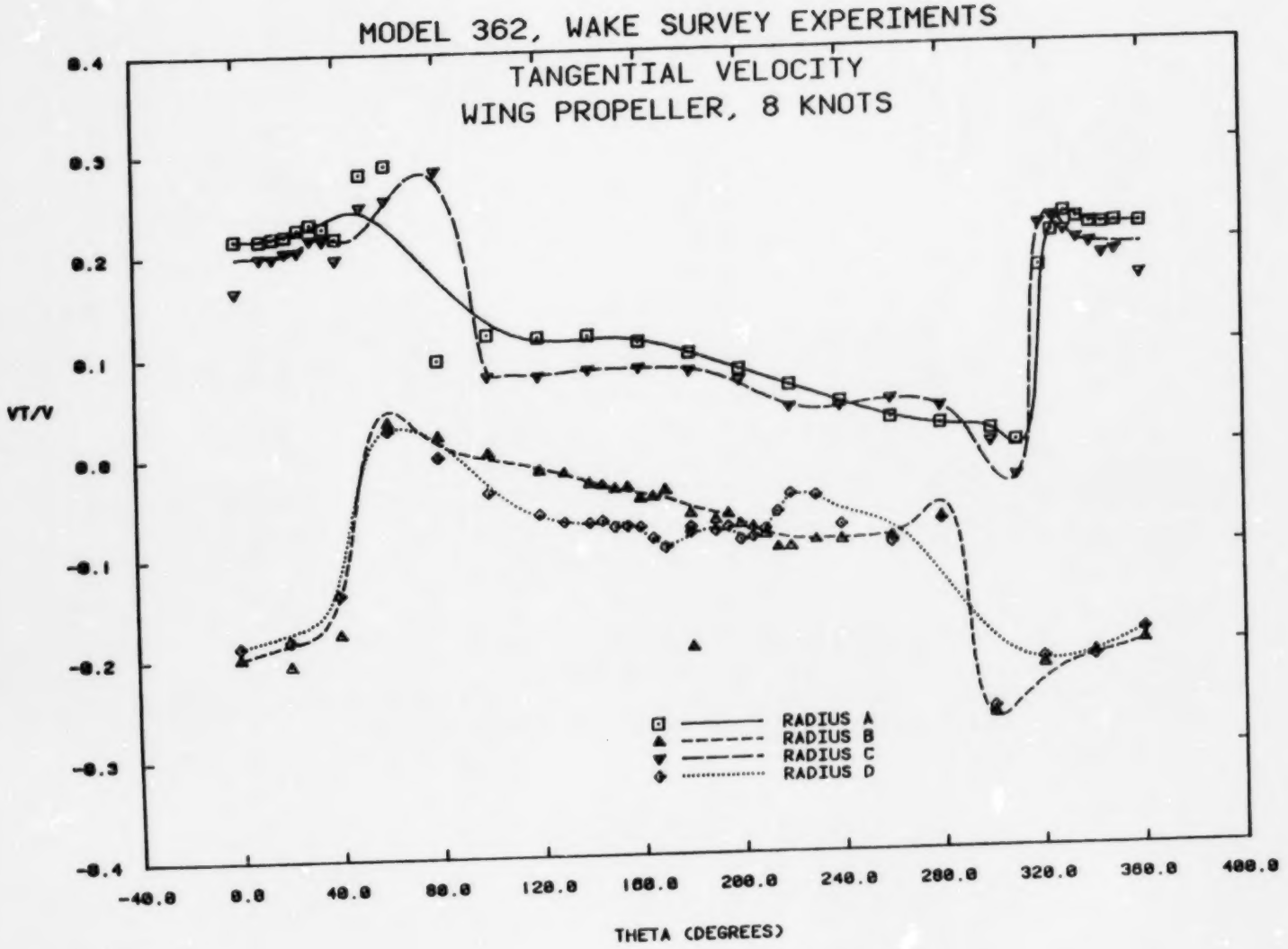

MODEL 362, WAKE SURVEY EXPERIMENTS
TANGENTIAL VELOCITY
WING PROPELLER, 8 KNOTS
VT/V
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-40.0
0.0
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 13

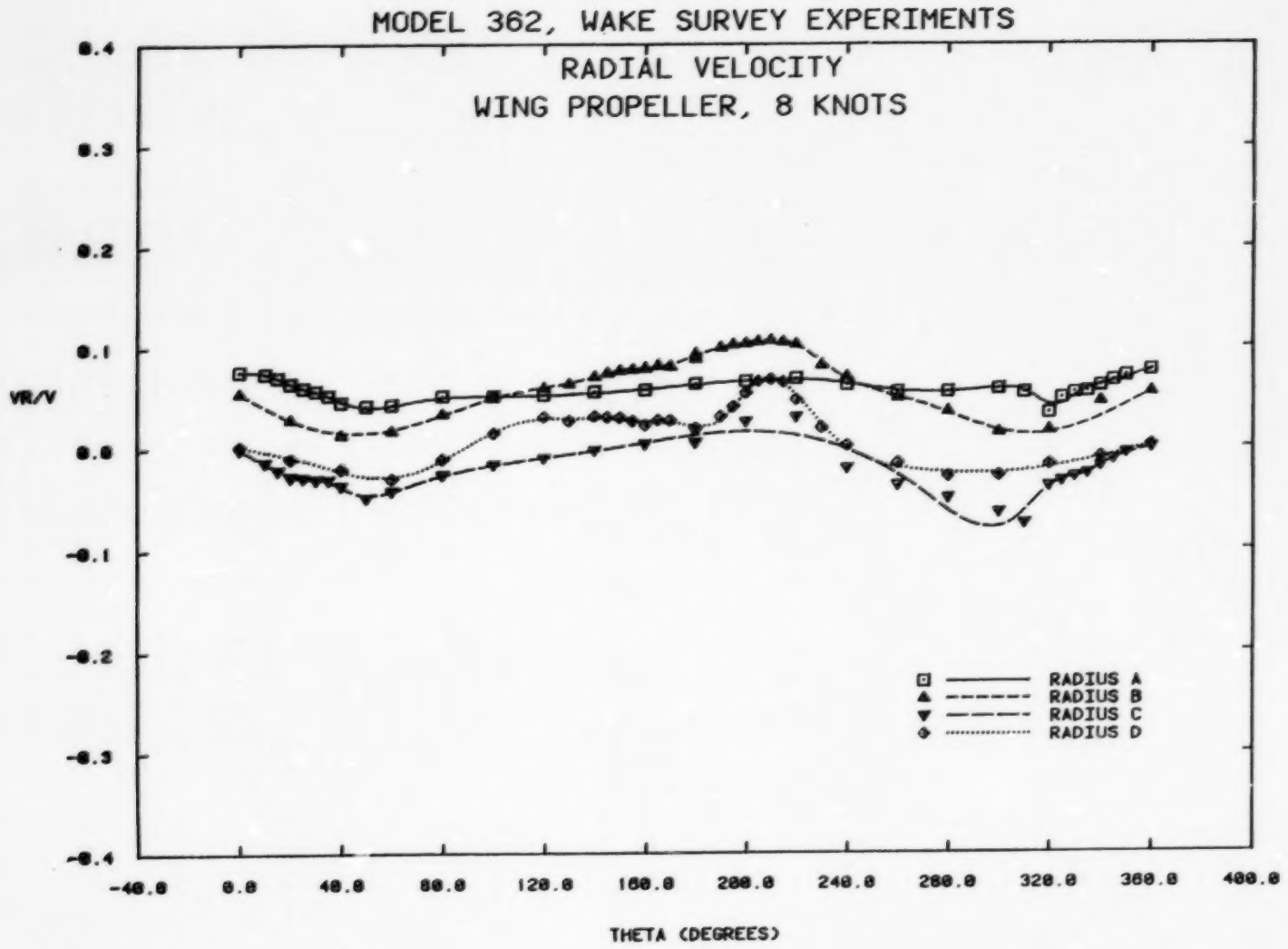

MODEL 362, WAKE SURVEY EXPERIMENTS
RADIAL VELOCITY
WING PROPELLER, 8 KNOTS
VR/V
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-40.0
0.0
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 14

WAKE SURVEY EXPERIMENTS

PORT SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25	m
DISPLACEMENT	68991	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
PROPELLER DIAMETER	6.83	m
SHIP SPEED	16.0	knots
FRACTIONAL RADIUS	0.324	

THETA	VX/V	VT/V	VR/V
0.000	0.802	0.046	0.108
10.000	0.811	0.047	0.104
20.000	0.828	0.063	0.093
30.000	0.848	0.014	0.080
40.000	0.836	0.023	0.066
50.000	0.818	0.077	0.054
60.000	0.883	0.089	0.048
70.000	0.914	0.099	0.045
80.000	0.925	0.109	0.045
90.000	0.935	0.119	0.046
100.000	0.944	0.127	0.048
110.000	0.953	0.130	0.049
120.000	0.963	0.126	0.051
130.000	0.974	0.115	0.052
140.000	0.984	0.100	0.053
150.000	0.992	0.083	0.055
160.000	0.999	0.067	0.059
170.000	1.003	0.051	0.062
180.000	1.006	0.035	0.066
190.000	1.007	0.017	0.069
200.000	1.006	-0.001	0.070
210.000	1.005	-0.021	0.071
220.000	1.004	-0.041	0.069
230.000	1.001	-0.060	0.067
240.000	0.998	-0.077	0.062
250.000	0.992	-0.088	0.058
260.000	0.981	-0.089	0.053
270.000	0.962	-0.074	0.049
280.000	0.938	-0.053	0.046
290.000	0.913	-0.046	0.043
300.000	0.894	-0.058	0.042
310.000	0.876	-0.060	0.046
320.000	0.858	-0.019	0.061
330.000	0.840	0.038	0.079
340.000	0.822	0.044	0.088
350.000	0.805	0.046	0.099
360.000	0.802	0.046	0.108

WAKE SURVEY EXPERIMENTS

PORT SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25	m
DISPLACEMENT	68991	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
PROPELLER DIAMETER	6.83	m
SHIP SPEED	16.0	knots
FRACTIONAL RADIUS	0.512	

THETA	VX/V	VT/V	VR/V
0.000	0.799	-0.077	0.079
10.000	0.802	-0.063	0.062
20.000	0.806	-0.050	0.046
30.000	0.814	-0.040	0.033
40.000	0.828	-0.033	0.024
50.000	0.851	-0.028	0.019
60.000	0.886	-0.023	0.019
70.000	0.921	-0.014	0.022
80.000	0.943	0.000	0.030
90.000	0.957	0.018	0.040
100.000	0.972	0.038	0.047
110.000	0.988	0.054	0.051
120.000	1.002	0.057	0.055
130.000	1.010	0.038	0.061
140.000	1.015	0.015	0.067
150.000	1.022	0.022	0.072
160.000	1.029	0.021	0.076
170.000	1.033	0.004	0.077
180.000	1.038	-0.019	0.084
190.000	1.042	-0.046	0.099
200.000	1.036	-0.074	0.108
210.000	1.027	-0.104	0.108
220.000	1.028	-0.118	0.105
230.000	1.034	-0.119	0.096
240.000	1.036	-0.116	0.081
250.000	1.033	-0.118	0.064
260.000	1.024	-0.127	0.049
270.000	1.008	-0.137	0.035
280.000	0.986	-0.142	0.024
290.000	0.959	-0.139	0.016
300.000	0.926	-0.128	0.015
310.000	0.893	-0.117	0.021
320.000	0.861	-0.111	0.032
330.000	0.836	-0.105	0.046
340.000	0.818	-0.100	0.058
350.000	0.807	-0.093	0.069
360.000	0.799	-0.077	0.079

WAKE SURVEY EXPERIMENTS

PORT SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25	m
DISPLACEMENT	68991	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
PROPELLER DIAMETER	6.83	m
SHIP SPEED	16.0	knots
FRACTIONAL RADIUS	0.701	

THETA	VX/V	VT/V	VR/V
0.000	0.717	-0.013	-0.007
10.000	0.654	0.003	-0.018
20.000	0.715	0.011	-0.031
30.000	0.782	0.021	-0.035
40.000	0.791	0.034	-0.050
50.000	0.794	0.051	-0.061
60.000	0.819	0.069	-0.054
70.000	0.853	0.082	-0.040
80.000	0.884	0.086	-0.029
90.000	0.910	0.084	-0.023
100.000	0.930	0.078	-0.019
110.000	0.947	0.071	-0.016
120.000	0.959	0.064	-0.012
130.000	0.969	0.059	-0.007
140.000	0.977	0.054	-0.003
150.000	0.984	0.050	0.002
160.000	0.992	0.046	0.006
170.000	0.999	0.042	0.009
180.000	1.005	0.036	0.013
190.000	1.009	0.028	0.016
200.000	1.009	0.017	0.019
210.000	1.008	0.004	0.021
220.000	1.005	-0.007	0.019
230.000	1.003	-0.016	0.011
240.000	1.003	-0.021	-0.003
250.000	1.003	-0.023	-0.021
260.000	1.002	-0.025	-0.038
270.000	0.996	-0.027	-0.049
280.000	0.983	-0.030	-0.055
290.000	0.955	-0.032	-0.060
300.000	0.906	-0.033	-0.064
310.000	0.859	-0.034	-0.064
320.000	0.836	-0.035	-0.050
330.000	0.808	-0.034	-0.037
340.000	0.748	-0.031	-0.030
350.000	0.720	-0.025	-0.015
360.000	0.717	-0.013	-0.007

WAKE SURVEY EXPERIMENTS

PORT SHAFT

MODEL NUMBER 362
PROTECTION OF PROPELLERS

IN ICE

SHIP LENGTH	224.25	m
DISPLACEMENT	68991	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
PROPELLER DIAMETER	6.83	m
SHIP SPEED	16.0	knots
FRACTIONAL RADIUS	0.890	

THETA	VX/V	VT/V	VR/V
0.000	0.639	0.000	0.004
10.000	0.626	0.000	-0.001
20.000	0.625	0.019	-0.009
30.000	0.649	0.045	-0.020
40.000	0.710	0.067	-0.033
50.000	0.794	0.082	-0.035
60.000	0.879	0.091	-0.027
70.000	0.944	0.093	-0.015
80.000	0.976	0.088	-0.002
90.000	0.987	0.078	0.010
100.000	0.992	0.066	0.019
110.000	1.001	0.055	0.025
120.000	1.017	0.046	0.030
130.000	1.042	0.038	0.034
140.000	1.064	0.031	0.038
150.000	1.059	0.023	0.040
160.000	1.066	0.017	0.040
170.000	1.077	0.010	0.041
180.000	1.081	0.005	0.043
190.000	1.090	0.002	0.050
200.000	1.108	0.001	0.074
210.000	1.073	0.010	0.083
220.000	1.006	0.023	0.060
230.000	0.984	0.027	0.028
240.000	1.017	0.017	0.009
250.000	1.056	0.000	-0.004
260.000	1.060	-0.019	-0.013
270.000	1.032	-0.037	-0.019
280.000	0.982	-0.051	-0.023
290.000	0.926	-0.060	-0.024
300.000	0.874	-0.063	-0.023
310.000	0.828	-0.061	-0.020
320.000	0.787	-0.057	-0.016
330.000	0.748	-0.051	-0.011
340.000	0.711	-0.043	-0.006
350.000	0.675	-0.026	-0.001
360.000	0.639	-0.002	0.004

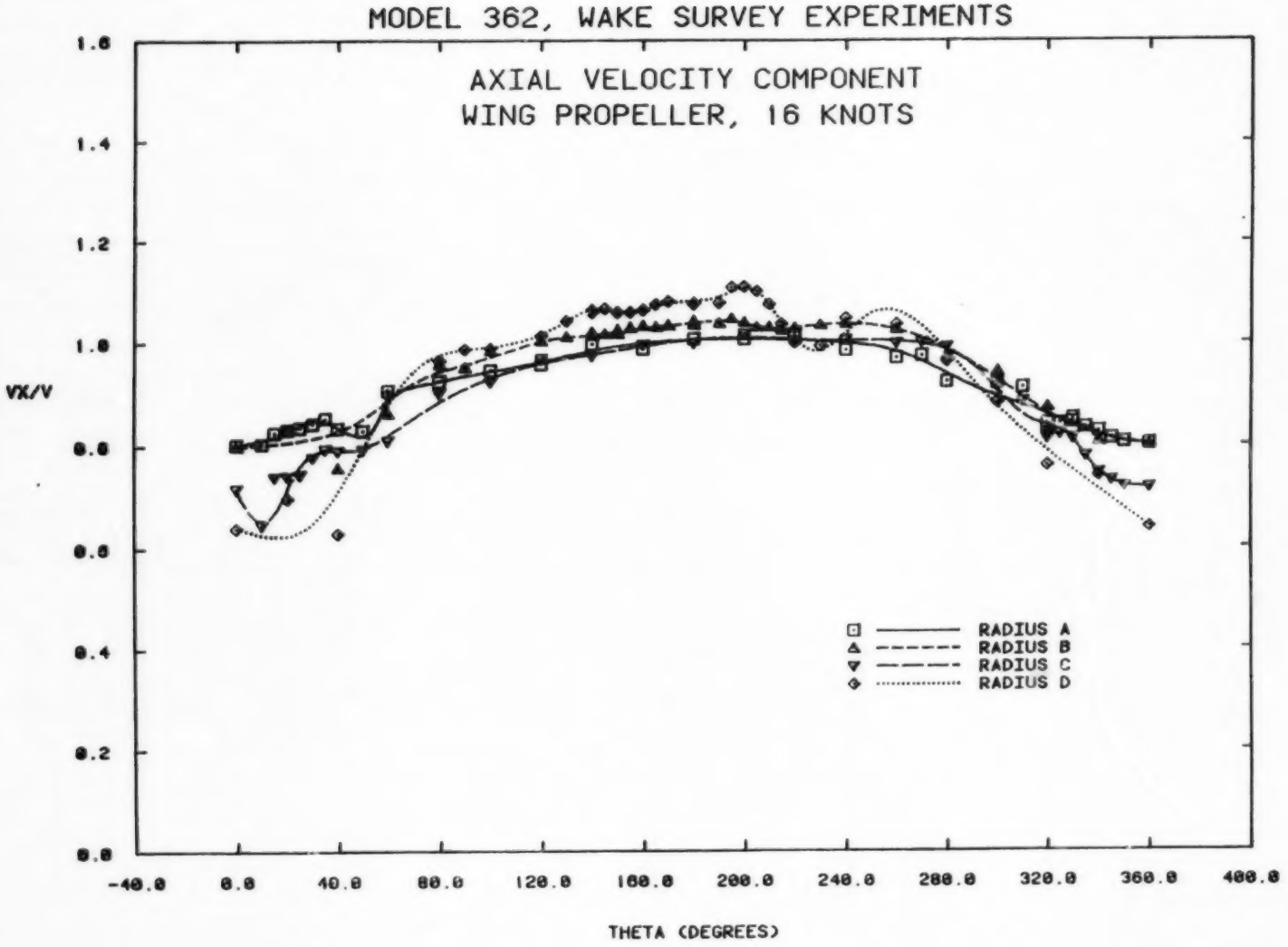
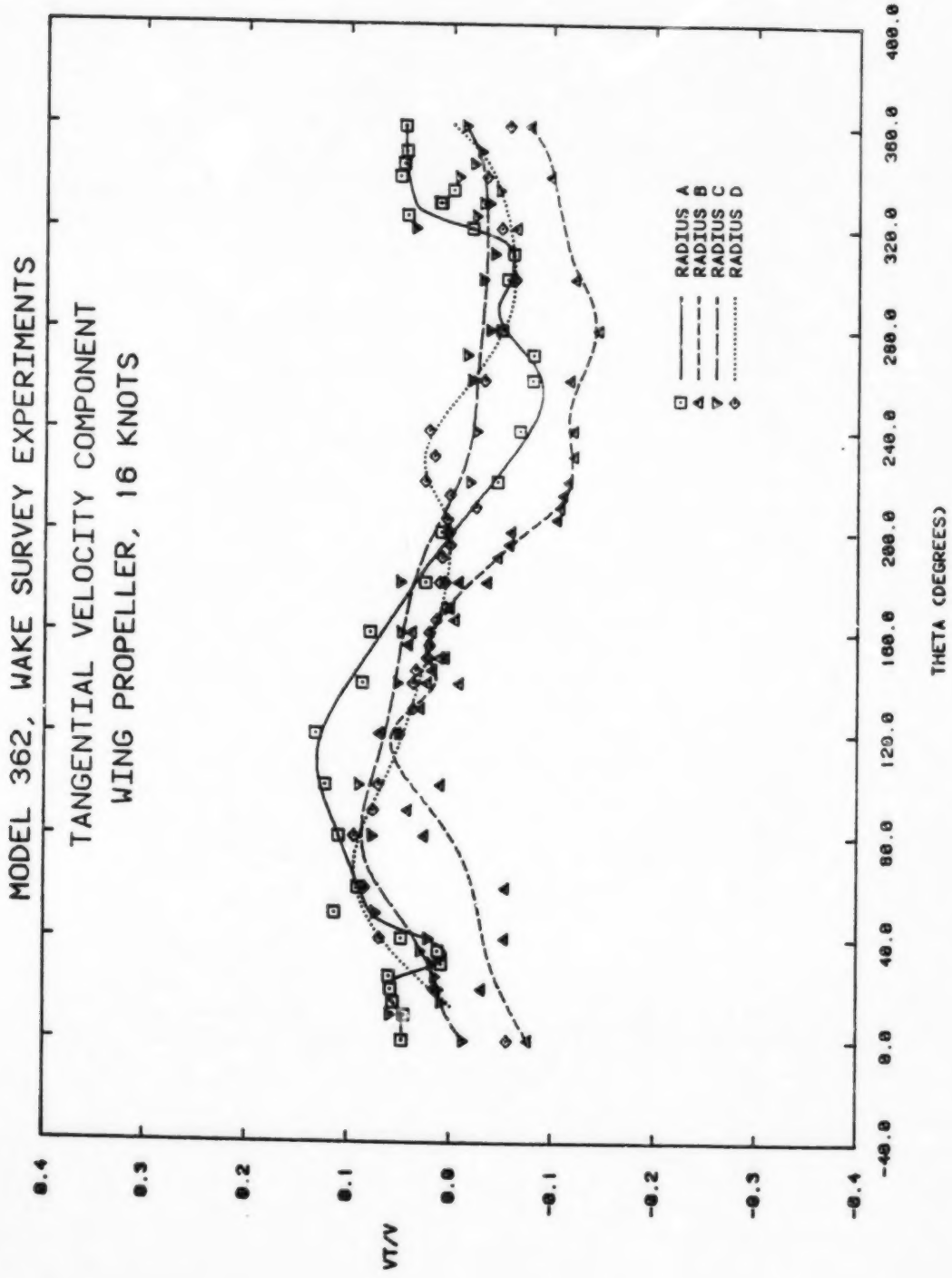

MODEL 362, WAKE SURVEY EXPERIMENTS
AXIAL VELOCITY COMPONENT
WING PROPELLER, 16 KNOTS
VX/V
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-40.0
0.0
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 15

Figure 16


MODEL 362, WAKE SURVEY EXPERIMENTS
TANGENTIAL VELOCITY COMPONENT
WING PROPELLER, 16 KNOTS
VT/V
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-40.0
0.0
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0

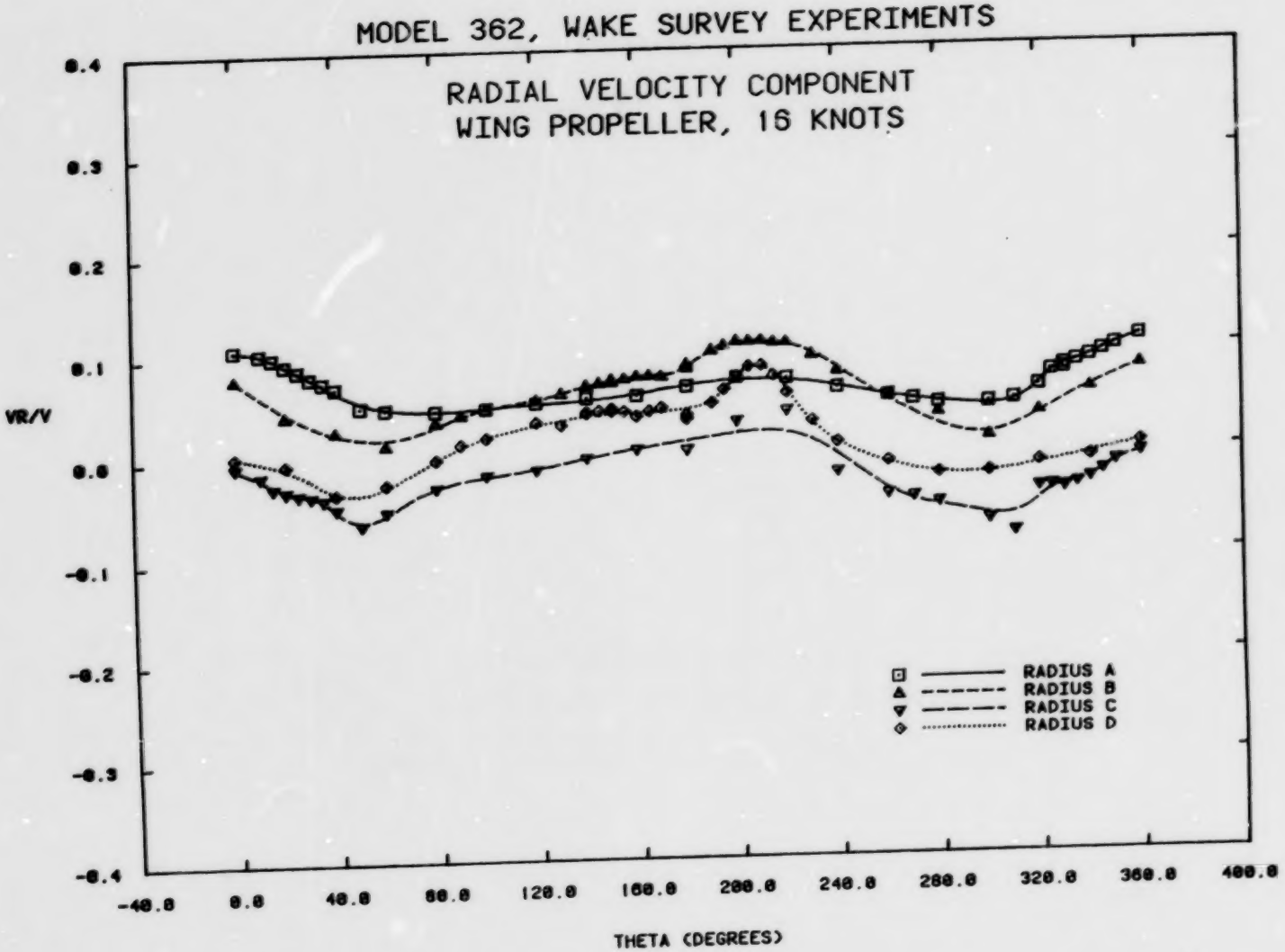

MODEL 362, WAKE SURVEY EXPERIMENTS
RADIAL VELOCITY COMPONENT
WING PROPELLER, 16 KNOTS
VR/V
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-40.0
0.0
40.0
80.0
120.0
160.0
200.0
240.0
280.0
320.0
360.0
400.0
THETA (DEGREES)
RADIUS A
RADIUS B
RADIUS C
RADIUS D

Figure 17

MODEL 382
WAKE SURVEY
8 KNOTS
CENTRE PROPELLER

CONTOURS OF
TAYLOR WAKE FRACTION

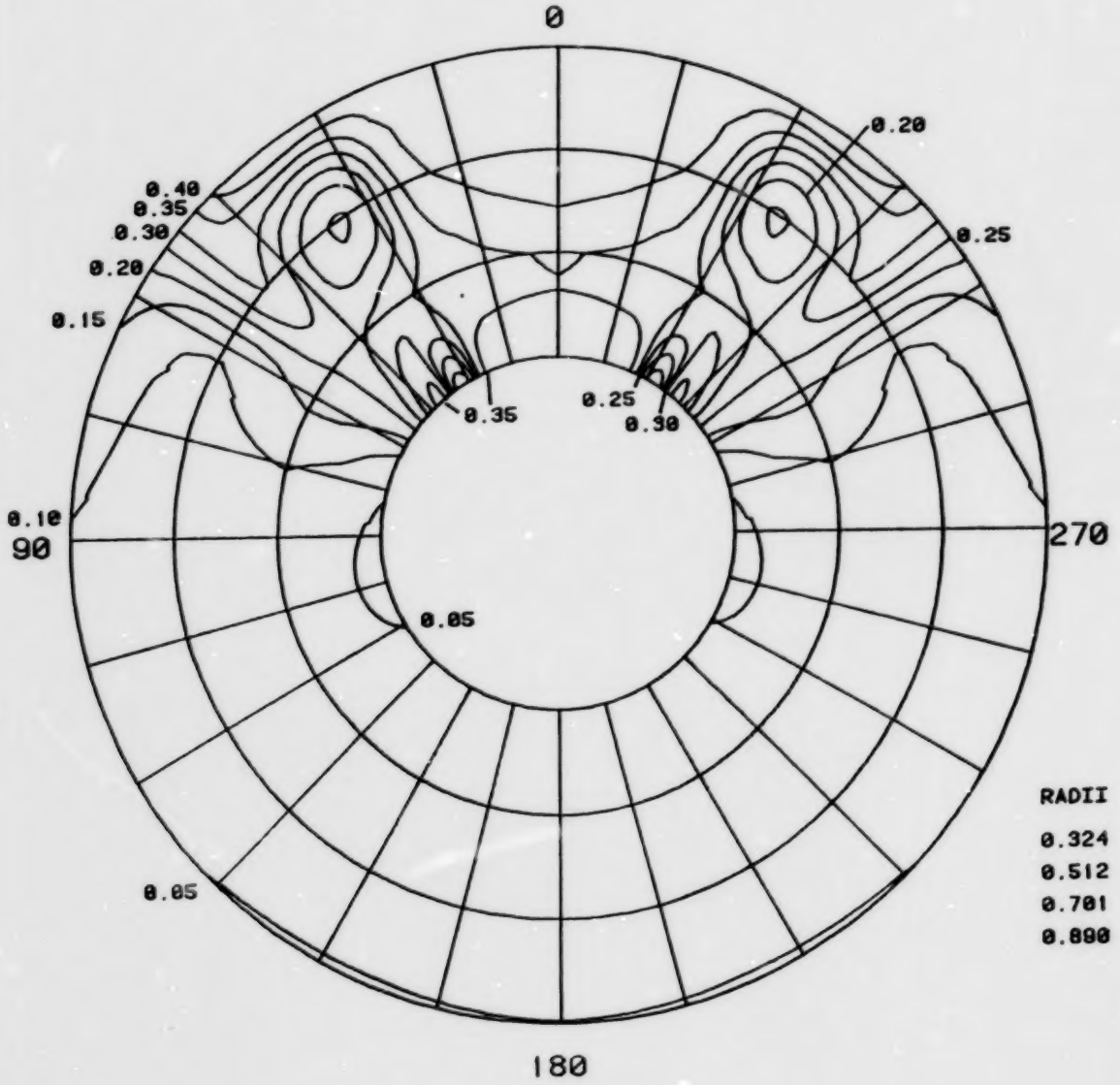


Figure 18

MODEL 382
WAKE SURVEY
18 KNOTS
CENTRE PROPELLER

CONTOURS OF
TAYLOR WAKE FRACTION

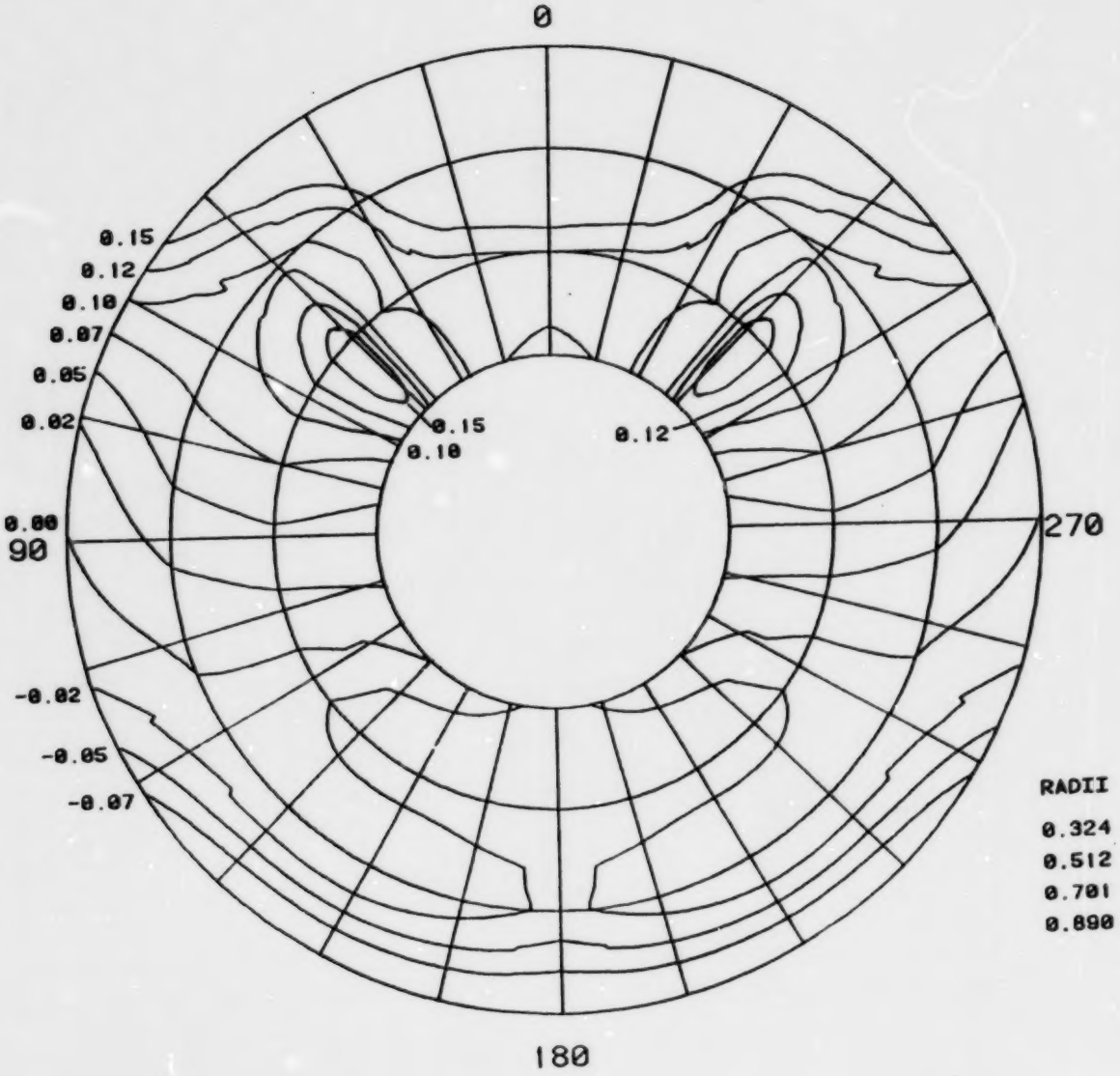


Figure 19

MODEL 302
WAKE SURVEY
8 KNOTS
WING PROPELLER

CONTOURS OF
TAYLOR WAKE FRACTION

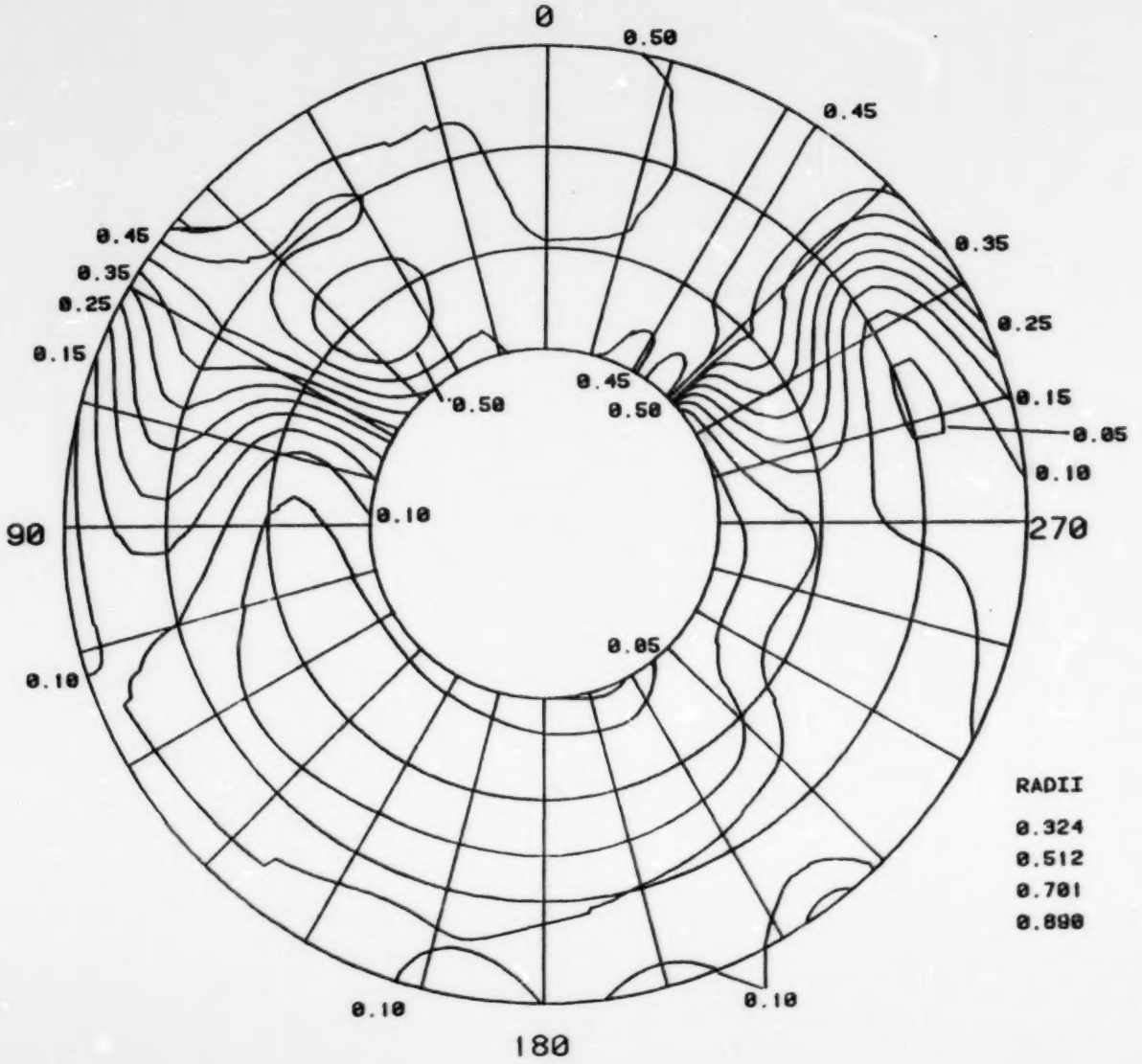


Figure 20

MODEL 362
WAKE SURVEY
18 KNOTS
WING PROPELLER

CONTOURS OF
TAYLOR WAKE FRACTION

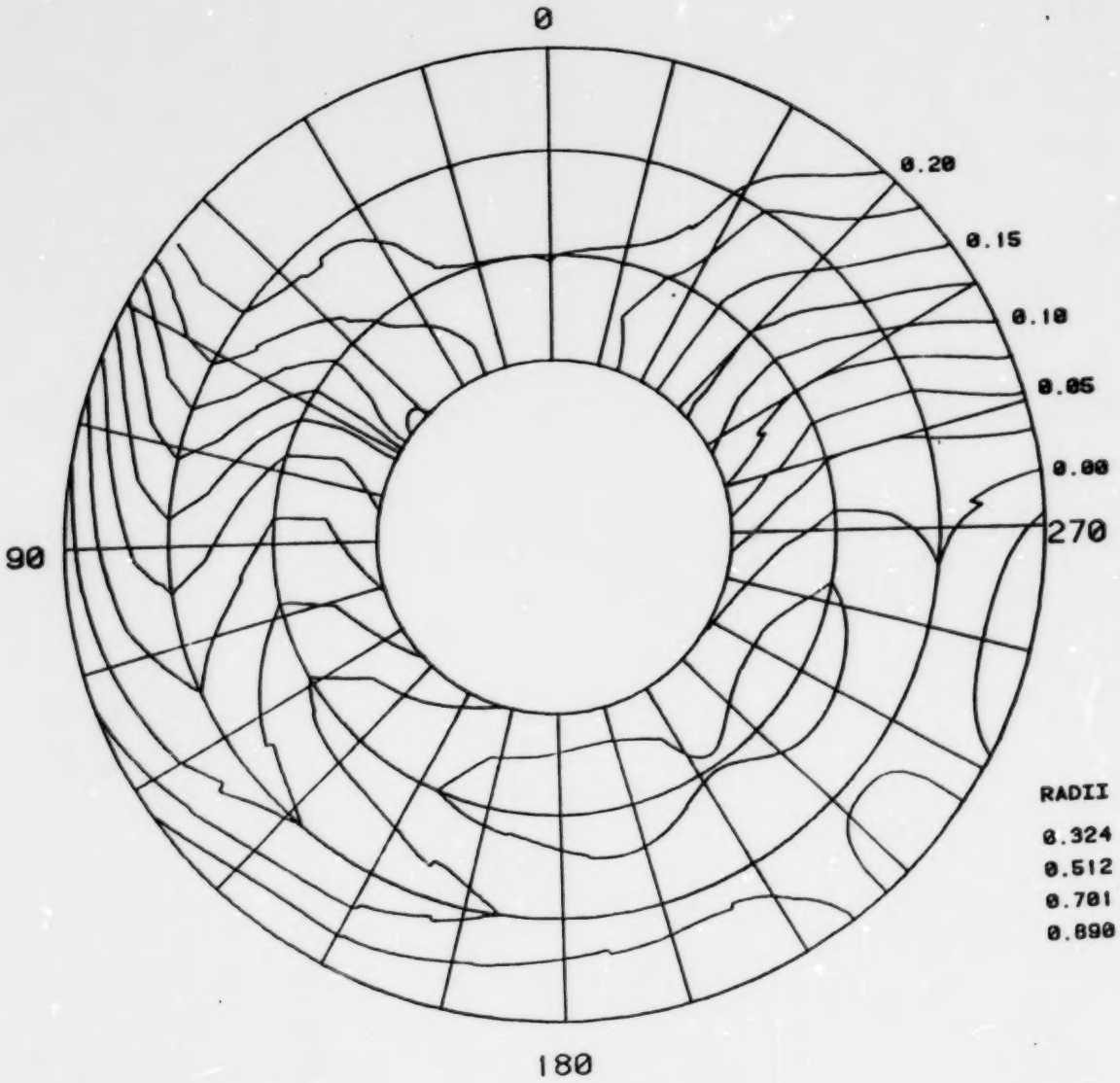


Figure 21

WAKE SURVEY
8 KNOTS
CENTRE PROPELLER
FLOW VECTORS

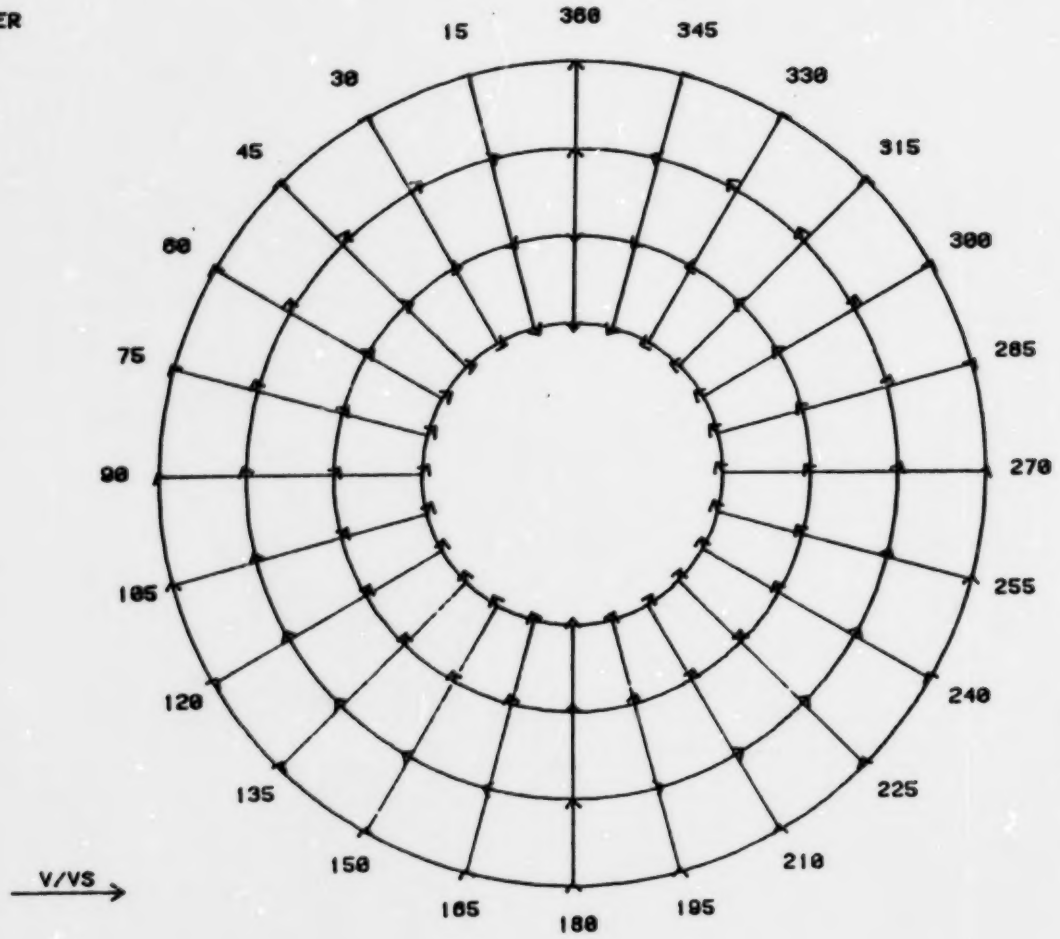
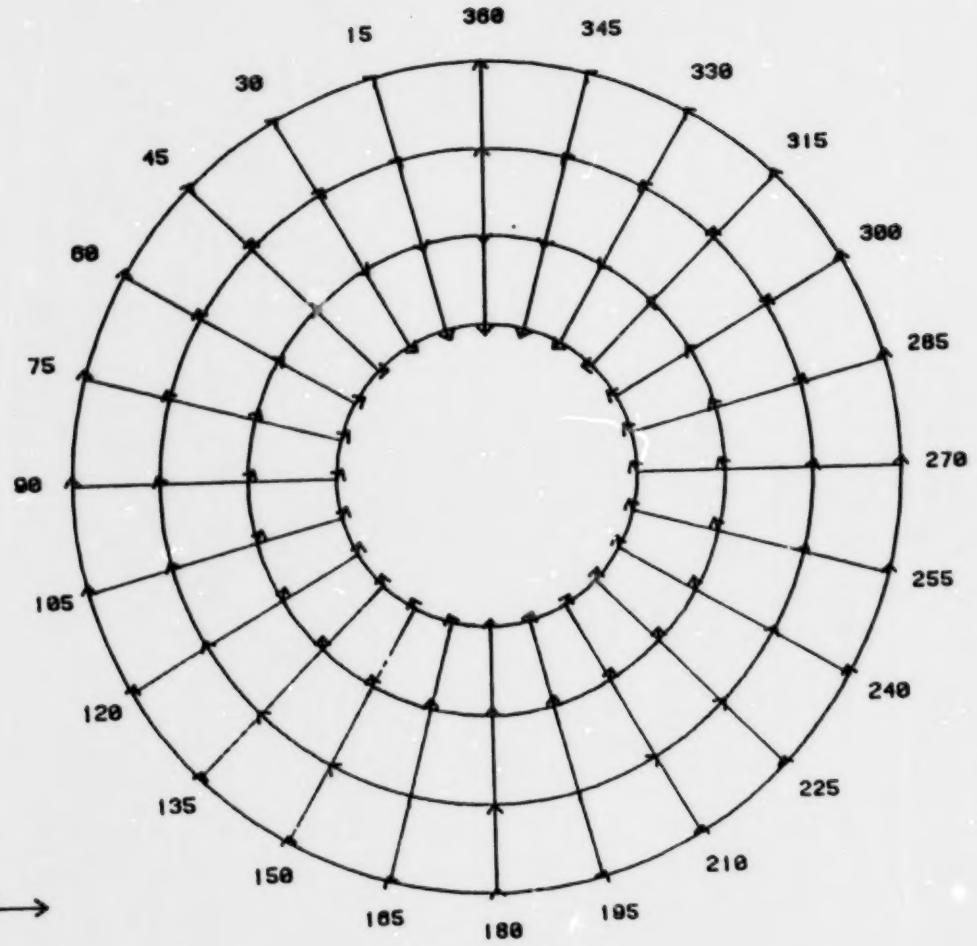


Figure 22

WAKE SURVEY
18 KNOTS
CENTRE PROPELLER
FLOW VECTORS



V/VS →

RADII

0.324
0.512
0.701
0.890

Figure 23

WAKE SURVEY
8 KNOTS
WING PROPELLER
FLOW VECTORS

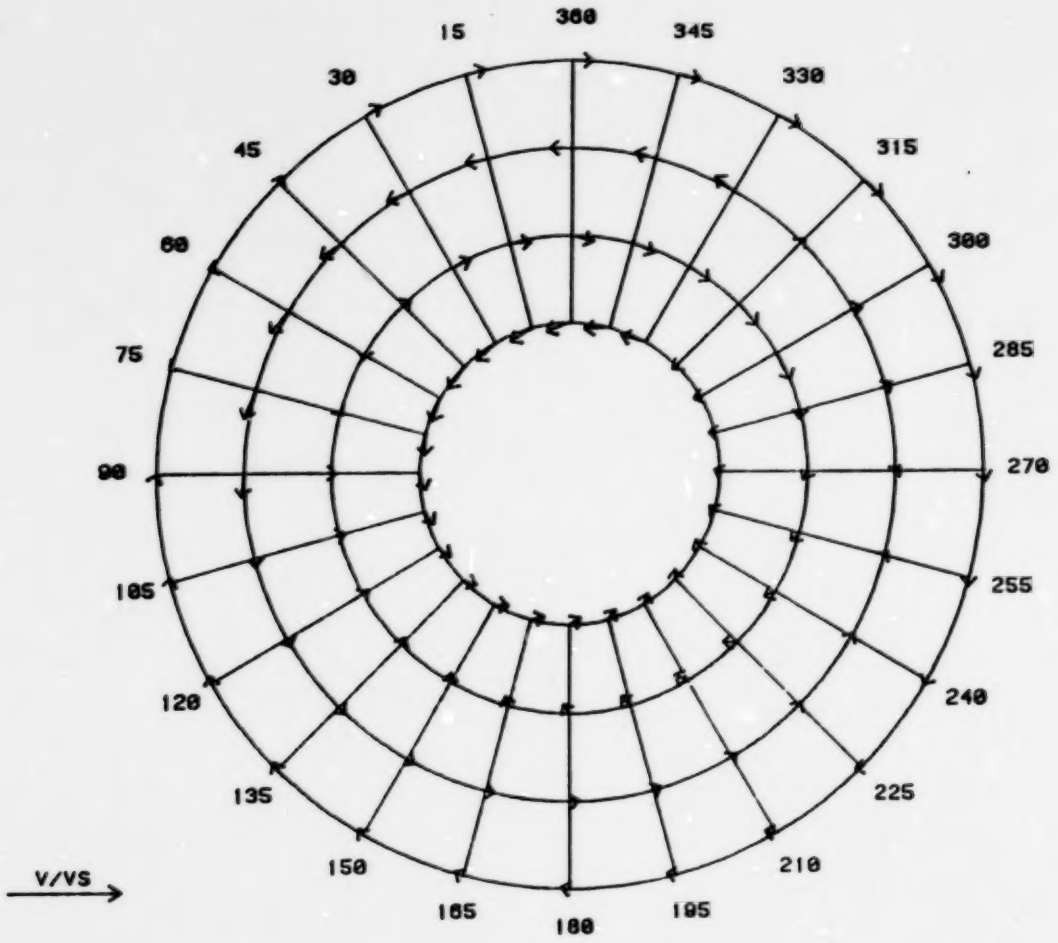
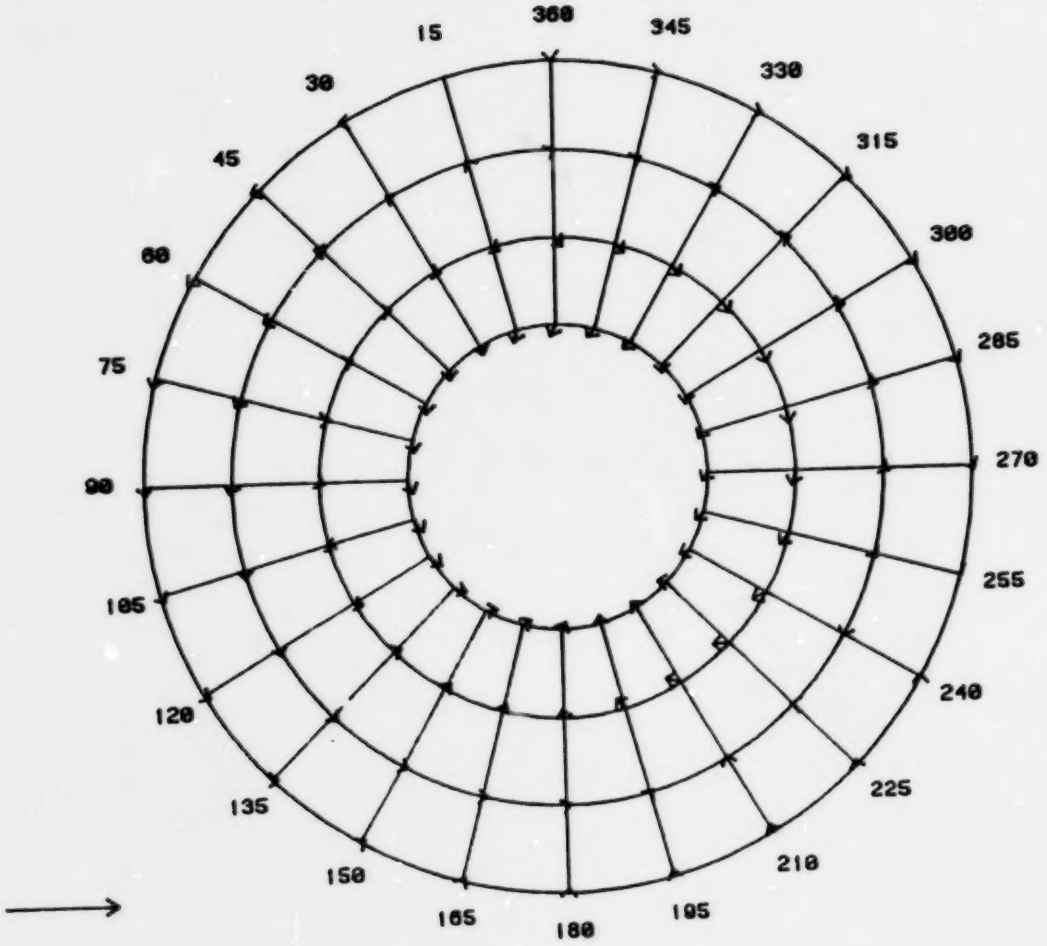


Figure 24

WAKE SURVEY
10 KNOTS
WING PROPELLER
FLOW VECTORS



RADII

0.324
0.512
0.701
0.830

Figure 25

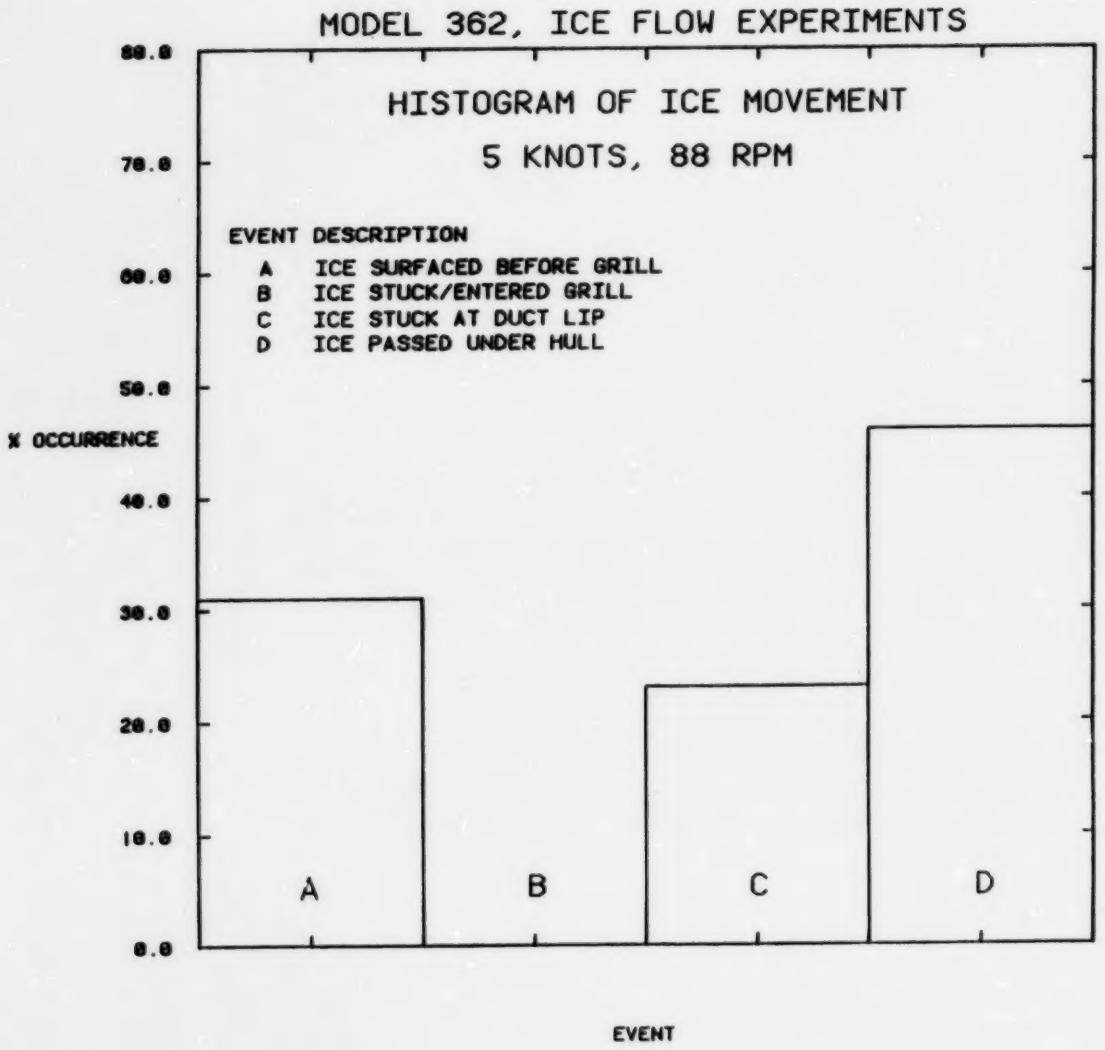

MODEL 362, ICE FLOW EXPERIMENTS
HISTOGRAM OF ICE MOVEMENT
5 KNOTS, 88 RPM
EVENT DESCRIPTION
A ICE SURFACED BEFORE GRILL
B ICE STUCK/ENTERED GRILL
C ICE STUCK AT DUCT LIP
D ICE PASSED UNDER HULL
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
% OCCURRENCE
A
B
C
D
EVENT

Figure 26

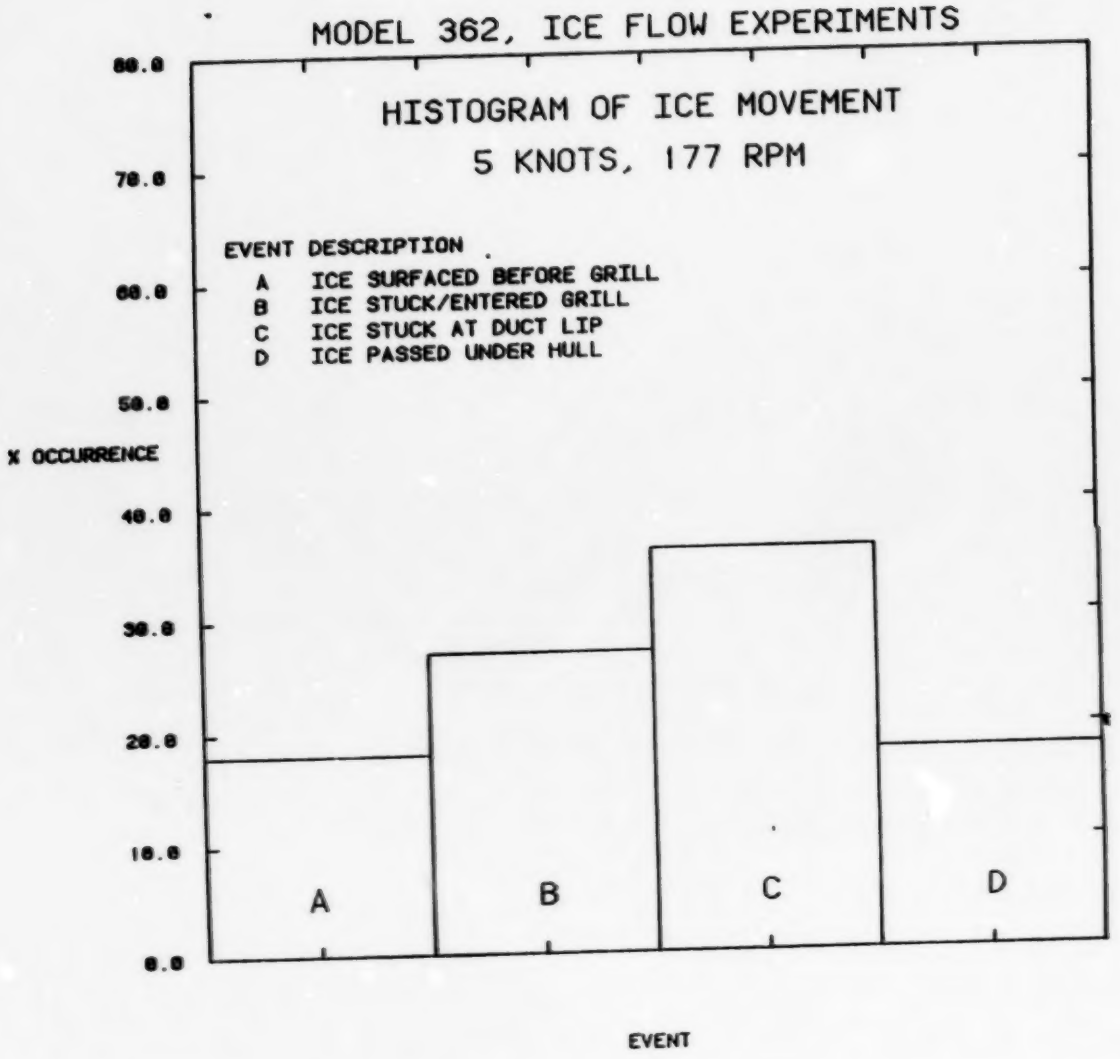

MODEL 362, ICE FLOW EXPERIMENTS
HISTOGRAM OF ICE MOVEMENT
5 KNOTS, 177 RPM
EVENT DESCRIPTION
A ICE SURFACED BEFORE GRILL
B ICE STUCK/ENTERED GRILL
C ICE STUCK AT DUCT LIP
D ICE PASSED UNDER HULL
% OCCURRENCE
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
A
B
C
D
EVENT

Figure 27

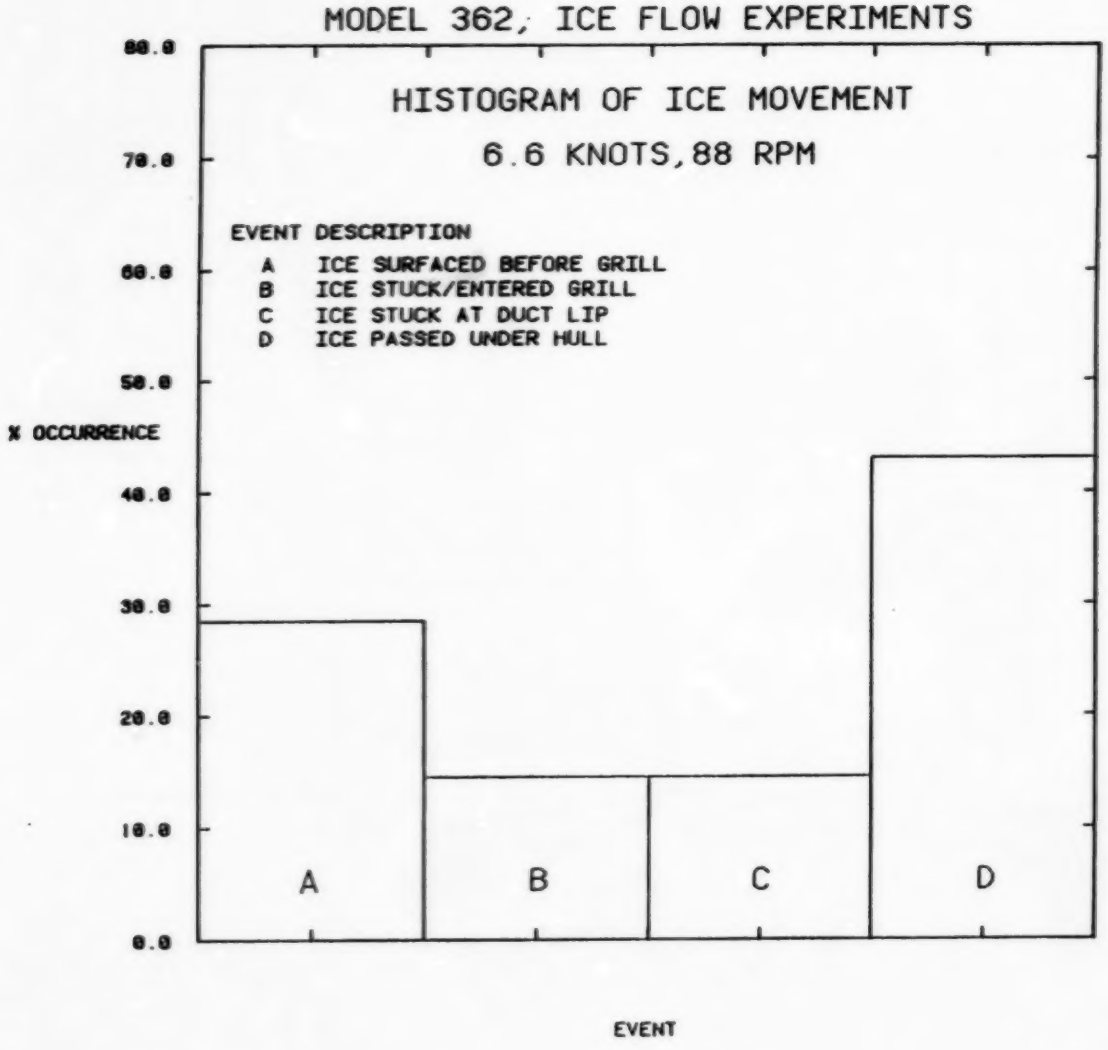

MODEL 362, ICE FLOW EXPERIMENTS
HISTOGRAM OF ICE MOVEMENT
6.6 KNOTS, 88 RPM
EVENT DESCRIPTION
A ICE SURFACED BEFORE GRILL
B ICE STUCK/ENTERED GRILL
C ICE STUCK AT DUCT LIP
D ICE PASSED UNDER HULL
% OCCURRENCE
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
A
B
C
D
EVENT

Figure 28

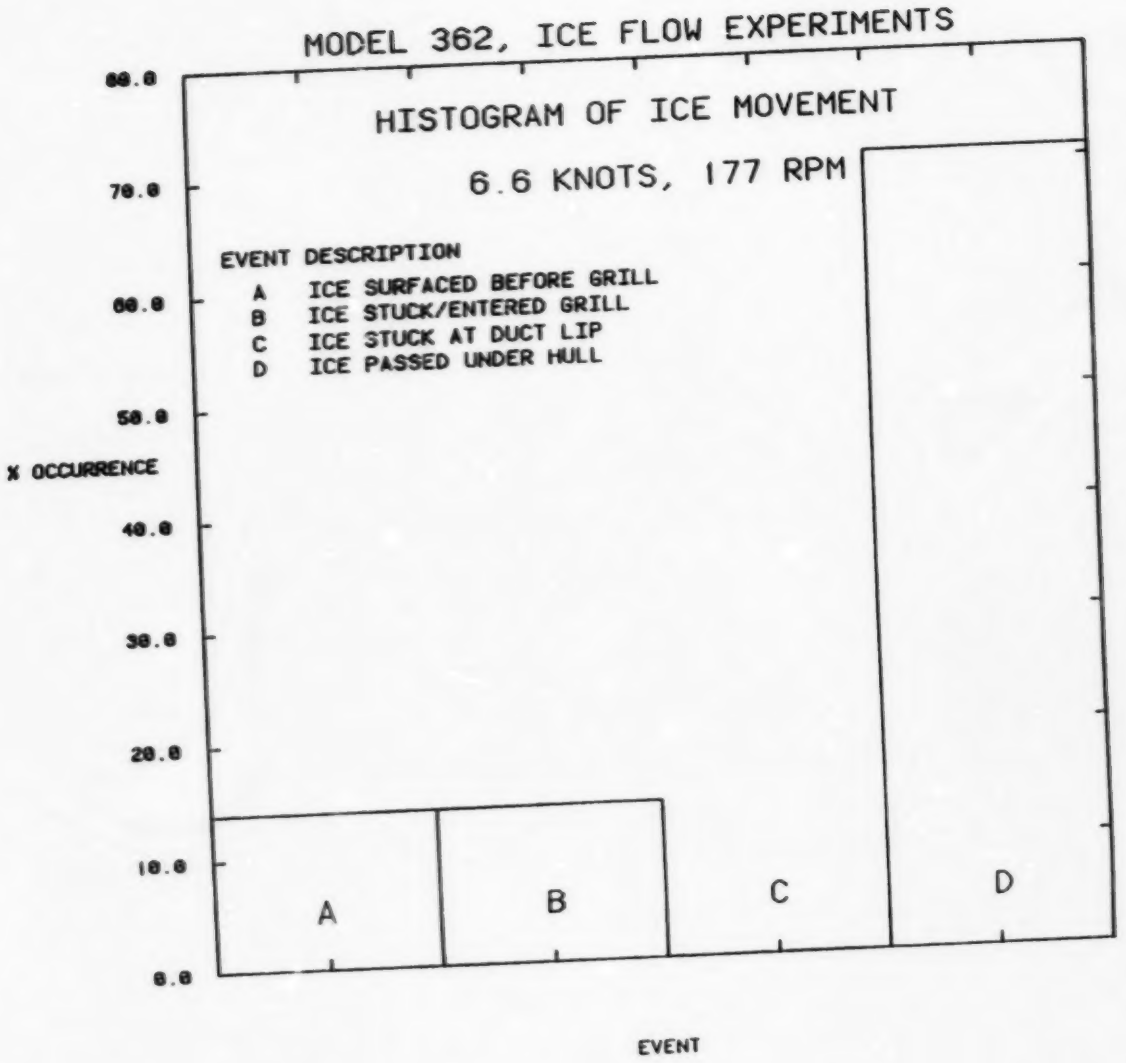

MODEL 362, ICE FLOW EXPERIMENTS
HISTOGRAM OF ICE MOVEMENT
6.6 KNOTS, 177 RPM
EVENT DESCRIPTION
A ICE SURFACED BEFORE GRILL
B ICE STUCK/ENTERED GRILL
C ICE STUCK AT DUCT LIP
D ICE PASSED UNDER HULL
% OCCURRENCE
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
A
B
C
D
EVENT

Figure 29

Table 35

MODEL 362

MANOEUVRING EXPERIMENTS
KEMPF ZIG-ZAG MANOEUVER WITH
UNEQUAL RUDDER AND HEADING
REVERSAL ANGLES

ALL RUDDER REVERSAL ANGLES = 30 DEGREES

10 DEGREE HEADING REVERSAL

MEAN SPEED (KNOTS)	Kmean	Tmean	K'	T'	STD/L
3.84	0.0086	99.94	0.869	0.989	4.4
3.73	0.0088	117.07	0.918	1.123	4.2
7.51	0.0182	49.27	0.941	0.953	4.1
7.55	0.0208	53.77	1.071	1.044	3.6
10.42	0.0295	40.48	1.100	1.086	3.5
10.51	0.0296	42.55	1.095	1.151	3.5

5 DEGREE HEADING REVERSAL

3.74	0.0088	101.27	0.914	0.975	4.2
3.93	0.0086	79.29	0.851	0.801	4.5
7.50	0.0218	60.02	1.129	1.159	3.4
7.48	0.0206	60.59	1.070	1.166	3.6
10.78	0.0289	45.24	1.041	1.256	3.7
10.80	0.0268	39.66	0.963	1.103	4.0
13.77	0.0385	36.28	1.086	1.286	3.5
13.63	0.0366	33.62	1.043	1.180	3.7

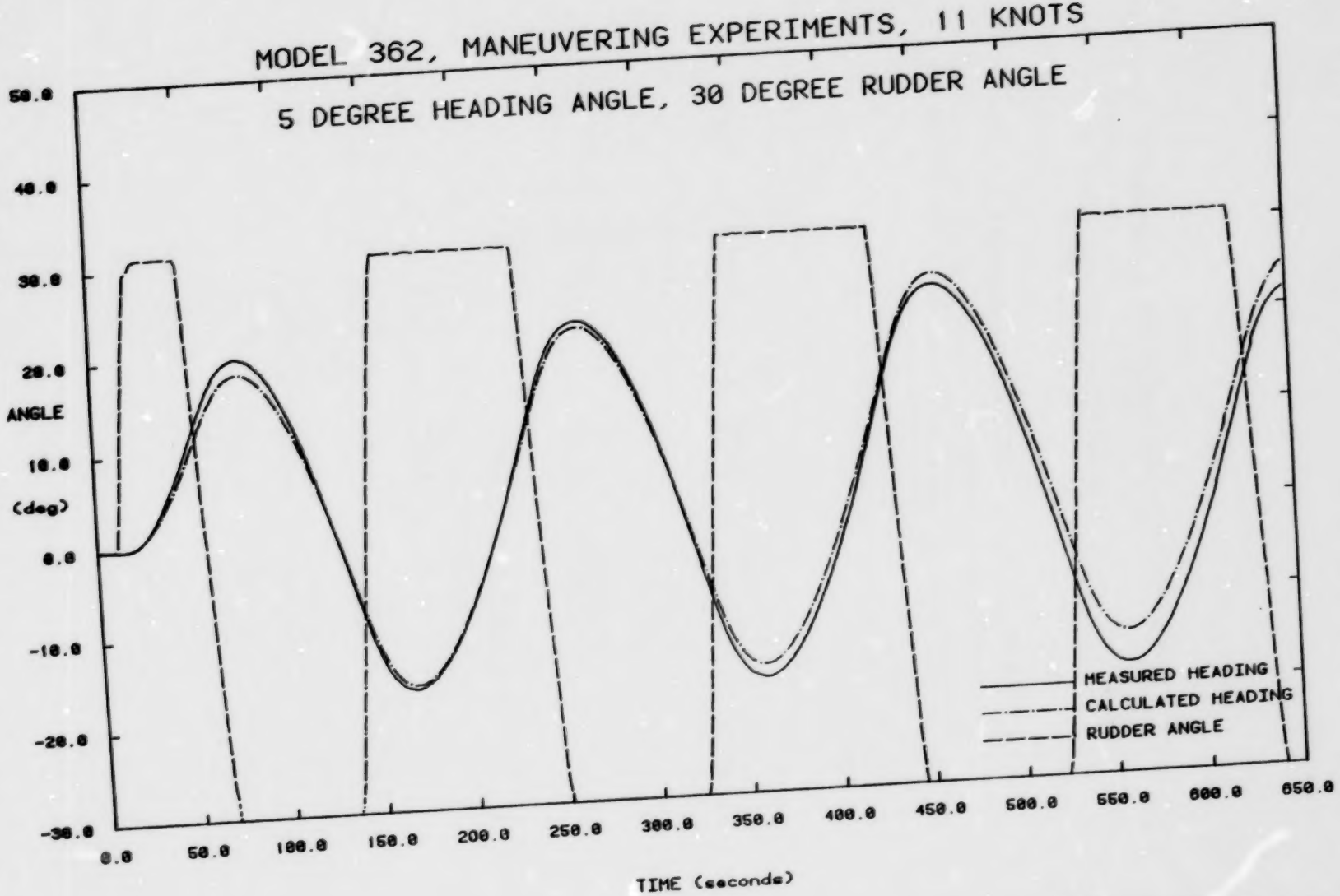

MODEL 362, MANEUVERING EXPERIMENTS, 11 KNOTS
5 DEGREE HEADING ANGLE, 30 DEGREE RUDDER ANGLE
50.0
40.0
30.0
20.0
ANGLE
10.0
(deg)
0.0
-10.0
-20.0
-30.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
TIME (seconds)
MEASURED HEADING
CALCULATED HEADING
RUDDER ANGLE

Figure 30

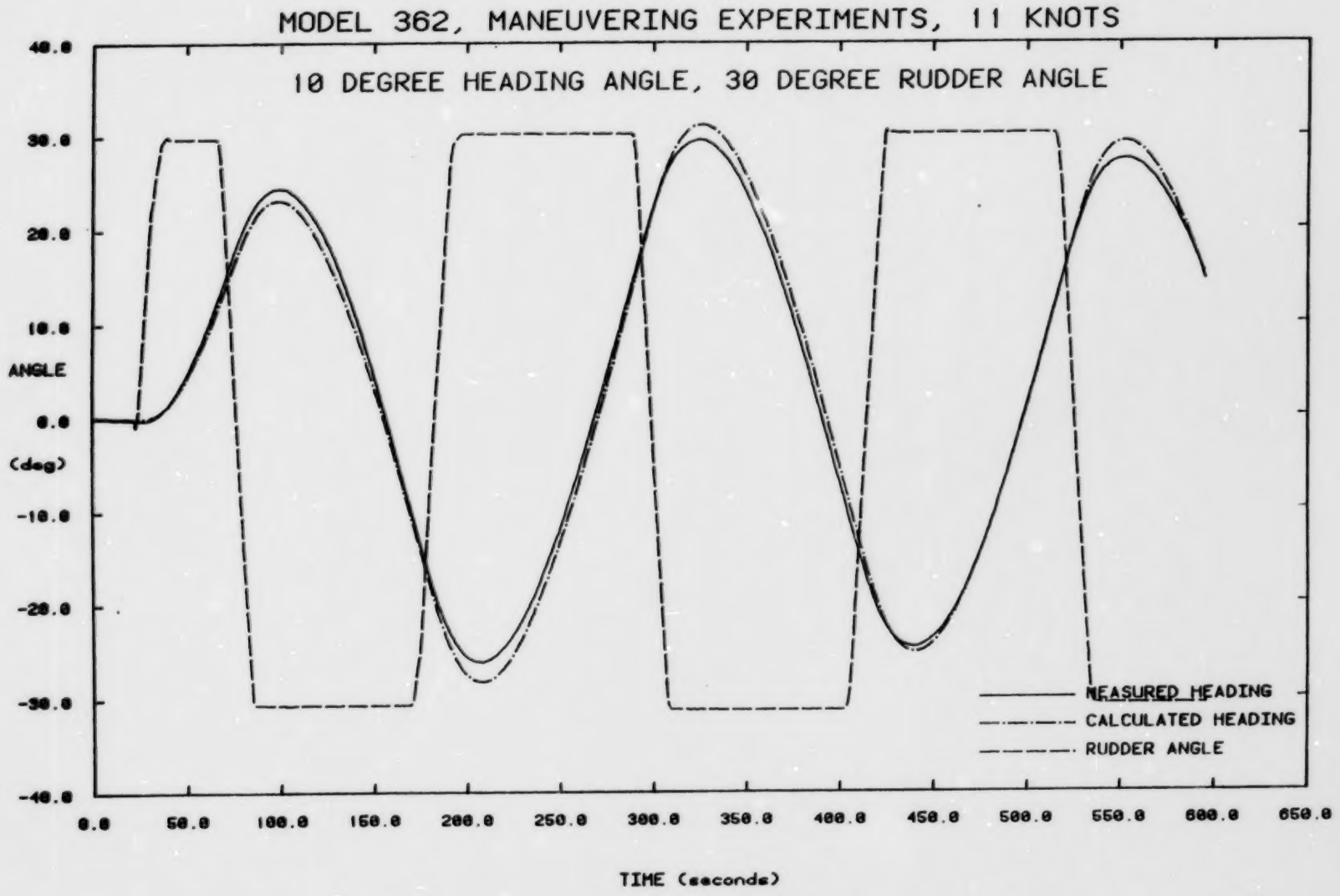

MODEL 362, MANEUVERING EXPERIMENTS, 11 KNOTS
10 DEGREE HEADING ANGLE, 30 DEGREE RUDDER ANGLE
40.0
30.0
20.0
10.0
ANGLE
0.0
(deg)
-10.0
-20.0
-30.0
-40.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
TIME (seconds)
MEASURED HEADING
CALCULATED HEADING
RUDDER ANGLE

Figure 31

APPENDIX B

RESISTANCE CALCULATIONS BASED UPON FLAT PLATE AND FORM FACTOR SKIN FRICTION CORRECTIONS -

MATERIAL SUPPLIED BY NRC WITH LETTER 11 MARCH 1986

LIST OF TABLES

	TABLE	PAGE
Summary of Model's Form Factors	1	B-1
Resistance Calculations for Flat Plate Skin Friction Corrections:		
Model No. 299	2	B-2
Model No. 299B grills fitted	3	B-3
Model No. 299B no grills fitted	4	B-4
Model No. 299C grills fitted	5	B-5
Model No. 299D bare hull	6	B-6
Model No. 299E outside walls only	7	B-7
Model No. 299F all walls	8	B-8
Form Frame Viscous (Scale Effect) Corrections:		
Model No. 299	9	B-9
Model No. 299B grills fitted	10	B-10
Model No. 299B no grills fitted	11	B-11
Model No. 299C grills fitted	12	B-12
Model No. 299D bare grills	13	B-13
Model No. 299E outside walls only	14	B-14
Model No. 299F all walls	15	B-15

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Comparison of Resistance Predictions based on Form Factor Viscoous Scale Effect Corrections	2	B-17
Ratios of Resistance Predictions, based on Flat Plate Skin Resistance Corrections, for the Various Models to those of Model No. 299	3	B-18
Ratios of Resistance Predictions, based on Form Factor Viscous Scale Effect Corrections, for the Various Models to those of Model No. 299	4	B-19

TABLE 1

SUMMARY OF MODEL'S FORM FACTORS

PROTECTION OF PROPELLERS IN ICE
PROHASKA FORM FACTOR (1 + k)

MODEL NUMBER	DESCRIPTION	(1 + k)
299	Normal Design	1.272
299B	Square Appendages & Grills	2.392
299B	Square Appendages, no Grills	2.016
299C	Square Appendages & Grills, Cruiser Stern	2.339
299D	Hull Only, no Appendages	1.504
299E	Rounded Appendages, no Grills, Outside Walls Only	1.652
299F	Rounded Appendages, no Grills, All Sidewalls	1.683
362	Arctec Design	2.385

TABLE 2

RESULTS OF RESISTANCE EXPERIMENTS
MODEL NUMBER 299
POLAR 7
REANALYSIS FOR FORM FACTOR

SHIP LENGTH	199.53	m
DISPLACEMENT	57113	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
SEA TEMPERATURE	15.0	deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	1439	294	0.110	4.900	1.092	2.661	0.253	1.648
10.00	1661	323	0.116	4.844	1.075	2.634	0.266	1.631
10.50	1909	353	0.122	4.799	1.066	2.615	0.279	1.619
11.00	2184	386	0.128	4.762	1.062	2.602	0.292	1.612
11.50	2487	420	0.134	4.730	1.062	2.593	0.306	1.606
12.00	2819	457	0.140	4.702	1.063	2.587	0.319	1.602
12.50	3180	495	0.145	4.677	1.066	2.582	0.332	1.599
13.00	3575	535	0.151	4.655	1.072	2.580	0.346	1.598
13.50	4007	577	0.157	4.639	1.081	2.583	0.359	1.600
14.00	4479	622	0.163	4.627	1.093	2.588	0.372	1.603
14.50	4990	669	0.169	4.618	1.107	2.596	0.385	1.608
15.00	5545	719	0.174	4.611	1.123	2.605	0.399	1.614
15.50	6150	771	0.180	4.609	1.142	2.619	0.412	1.622
16.00	6809	827	0.186	4.612	1.165	2.636	0.425	1.633
16.50	7530	887	0.192	4.620	1.193	2.658	0.439	1.646
17.00	8319	951	0.198	4.633	1.225	2.685	0.452	1.663
17.50	9184	1020	0.204	4.652	1.263	2.717	0.465	1.683
18.00	10125	1093	0.209	4.675	1.303	2.753	0.479	1.705
18.50	11139	1170	0.215	4.700	1.345	2.790	0.492	1.728
19.00	12234	1252	0.221	4.727	1.388	2.828	0.505	1.752
19.50	13426	1338	0.227	4.758	1.435	2.871	0.518	1.778
20.00	14754	1434	0.233	4.801	1.493	2.924	0.532	1.811
20.50	16262	1542	0.238	4.859	1.566	2.993	0.545	1.854
21.00	17976	1664	0.244	4.933	1.655	3.078	0.558	1.906
21.50	19920	1801	0.250	5.024	1.759	3.178	0.572	1.969
22.00	22142	1956	0.256	5.133	1.882	3.297	0.585	2.042
22.50	24717	2135	0.262	5.267	2.029	3.441	0.598	2.131
23.00	27800	2350	0.267	5.440	2.215	3.623	0.611	2.244
23.50	31567	2611	0.273	5.665	2.453	3.857	0.625	2.389
24.00	36032	2918	0.279	5.933	2.732	4.133	0.638	2.560
24.50	41151	3265	0.285	6.228	3.040	4.437	0.651	2.748
25.00	46984	3653	0.291	6.551	3.374	4.768	0.665	2.953
25.50	53600	4086	0.297	6.901	3.735	5.126	0.678	3.175
26.00	60951	4557	0.302	7.266	4.111	5.499	0.691	3.406

AEQ10CM8?S83DNR10-B4R

MODEL NUMBER 299
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.
INPUT TAGS N1 = 1 N2

OUTPUT FILENAME: M29?
OUTPUT TAGS N1 = 1 N2

PROGRAM RSP32 RUN BY
AT 10:50:59 ON 10-MAR

MODEL NUMBER 299B
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.
INPUT TAGS N1 = 3 N2

OUTPUT FILENAME: M299
OUTPUT TAGS N1 = 1 N2

TABLE 3
RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299B
FORM FACTOR ANALYSIS
GRILLS FITTED

SHIP LENGTH	200.00 m
DISPLACEMENT	70064 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	5102	1044	0.110	8.861	5.056	6.624	0.244	5.100
10.00	5985	1163	0.116	8.871	5.104	6.662	0.257	5.129
10.50	6964	1289	0.122	8.879	5.147	6.696	0.270	5.156
11.00	8044	1422	0.128	8.886	5.187	6.727	0.283	5.180
11.50	9231	1560	0.134	8.891	5.224	6.755	0.295	5.201
12.00	10528	1705	0.139	8.895	5.258	6.781	0.308	5.221
12.50	11940	1857	0.145	8.898	5.289	6.805	0.321	5.239
13.00	13474	2015	0.151	8.900	5.318	6.826	0.334	5.256
13.50	15133	2179	0.157	8.901	5.345	6.846	0.347	5.271
14.00	16925	2350	0.163	8.903	5.371	6.865	0.360	5.286
14.50	18855	2528	0.168	8.905	5.396	6.884	0.373	5.300
15.00	20929	2712	0.174	8.907	5.420	6.902	0.385	5.315
15.50	23154	2904	0.180	8.910	5.444	6.920	0.398	5.329
16.00	25536	3102	0.186	8.914	5.469	6.939	0.411	5.343
16.50	28084	3309	0.192	8.919	5.494	6.958	0.424	5.358
17.00	30807	3523	0.197	8.926	5.520	6.979	0.437	5.374
17.50	33714	3745	0.203	8.936	5.547	7.002	0.450	5.391
18.00	36814	3976	0.209	8.947	5.576	7.026	0.463	5.410
18.50	40114	4215	0.215	8.961	5.607	7.052	0.475	5.430
19.00	43634	4464	0.221	8.978	5.640	7.081	0.488	5.452
19.50	47397	4725	0.227	9.001	5.679	7.115	0.501	5.478
20.00	51417	4997	0.232	9.029	5.722	7.154	0.514	5.508
20.50	55702	5282	0.238	9.061	5.769	7.196	0.527	5.541
21.00	60269	5579	0.244	9.098	5.820	7.243	0.540	5.577
21.50	65144	5890	0.250	9.140	5.877	7.296	0.552	5.618
22.00	70390	6219	0.256	9.192	5.943	7.358	0.565	5.665
22.50	76072	6572	0.261	9.259	6.022	7.433	0.578	5.724
23.00	82162	6944	0.267	9.332	6.109	7.516	0.591	5.787
23.50	88666	7334	0.273	9.412	6.200	7.604	0.604	5.855
24.00	95925	7769	0.279	9.522	6.323	7.723	0.617	5.947
24.50	104352	8279	0.285	9.688	6.501	7.898	0.630	6.081
25.00	113852	8852	0.290	9.892	6.716	8.110	0.642	6.245

PROGRAM PSP33 RUN BY
AT 10:54:13 ON 10-MAR-

MODEL NUMBER 299B
CONDITION NUMBER 2
TEST NUMBER 0

INPUT FILENAME: N299.I
INPUT TAGS N1 = 2 N2 =

OUTPUT FILENAME: N299(
OUTPUT TAGS N1 = 2 N2

TABLE 4
RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299B
FORM FACTOR ANALYSIS
NO GRILLS FITTED

SHIP LENGTH	200.00	m
DISPLACEMENT	70044	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
SEA TEMPERATURE	15.0	deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	3663	750	0.110	7.504	3.698	5.266	0.244	3.662
10.00	4300	836	0.116	7.509	3.742	5.300	0.257	3.686
10.50	5008	927	0.122	7.515	3.783	5.332	0.270	3.708
11.00	5792	1024	0.128	7.523	3.824	5.364	0.283	3.730
11.50	6658	1125	0.134	7.532	3.865	5.396	0.296	3.753
12.00	7610	1233	0.139	7.543	3.905	5.429	0.308	3.775
12.50	8652	1346	0.145	7.554	3.945	5.460	0.321	3.797
13.00	9789	1464	0.151	7.566	3.984	5.492	0.334	3.819
13.50	11025	1588	0.157	7.579	4.022	5.524	0.347	3.841
14.00	12369	1717	0.163	7.594	4.062	5.556	0.360	3.864
14.50	13826	1854	0.168	7.611	4.102	5.590	0.373	3.888
15.00	15401	1996	0.174	7.630	4.143	5.625	0.385	3.912
15.50	17097	2144	0.180	7.649	4.183	5.659	0.398	3.935
16.00	18917	2298	0.186	7.668	4.222	5.693	0.411	3.959
16.50	20871	2459	0.192	7.687	4.262	5.727	0.424	3.982
17.00	22970	2626	0.197	7.710	4.303	5.763	0.437	4.008
17.50	25229	2802	0.203	7.736	4.348	5.802	0.450	4.035
18.00	27651	2986	0.209	7.765	4.395	5.844	0.463	4.064
18.50	30237	3177	0.215	7.795	4.442	5.886	0.475	4.093
19.00	33008	3377	0.221	7.829	4.492	5.932	0.488	4.125
19.50	35995	3588	0.227	7.870	4.548	5.984	0.501	4.161
20.00	39205	3810	0.232	7.916	4.609	6.041	0.514	4.201
20.50	42639	4043	0.238	7.965	4.674	6.101	0.527	4.242
21.00	46314	4287	0.244	8.018	4.741	6.164	0.540	4.287
21.50	50262	4544	0.250	8.078	4.815	6.234	0.552	4.335
22.00	54562	4821	0.256	8.151	4.901	6.316	0.565	4.392
22.50	59299	5123	0.261	8.242	5.006	6.417	0.578	4.462
23.00	64448	5447	0.267	8.345	5.121	6.529	0.591	4.540
23.50	69978	5788	0.273	8.454	5.242	6.646	0.604	4.622
24.00	76074	6162	0.279	8.582	5.383	6.783	0.617	4.717
24.50	82959	6582	0.285	8.744	5.556	6.953	0.630	4.835
25.00	90580	7043	0.290	8.928	5.752	7.146	0.642	4.969

TABLE 5

RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299C
FORM FACTOR ANALYSIS
GRILLS FITTED

SHIP LENGTH	200.00 m
DISPLACEMENT	70506 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTH(15) X1000	CR X1000	CTS X1000	FNVOL	CTVOL X100
9.50	4981	1019	0.110	8.651	4.845	6.414	0.244	4.958
10.00	5846	1136	0.116	8.663	4.896	6.454	0.257	4.989
10.50	6803	1259	0.122	8.671	4.939	6.488	0.270	5.016
11.00	7856	1388	0.128	8.675	4.976	6.516	0.282	5.037
11.50	9010	1523	0.134	8.676	5.009	6.540	0.295	5.056
12.00	10268	1663	0.139	8.674	5.036	6.560	0.308	5.071
12.50	11633	1809	0.145	8.669	5.060	6.575	0.321	5.083
13.00	13111	1960	0.151	8.662	5.080	6.588	0.334	5.093
13.50	14707	2118	0.157	8.654	5.098	6.599	0.347	5.101
14.00	16425	2280	0.163	8.646	5.113	6.608	0.359	5.108
14.50	18266	2449	0.168	8.635	5.126	6.614	0.372	5.113
15.00	20241	2623	0.174	8.626	5.139	6.621	0.385	5.118
15.50	22362	2804	0.180	8.619	5.153	6.629	0.398	5.125
16.00	24634	2993	0.186	8.614	5.169	6.639	0.411	5.133
16.50	27062	3188	0.192	8.611	5.186	6.650	0.424	5.141
17.00	29661	3392	0.197	8.612	5.205	6.665	0.436	5.152
17.50	32450	3604	0.203	8.618	5.230	6.684	0.449	5.167
18.00	35432	3826	0.209	8.628	5.257	6.707	0.462	5.185
18.50	38609	4057	0.215	8.641	5.287	6.732	0.475	5.204
19.00	42010	4298	0.221	8.659	5.321	6.761	0.488	5.227
19.50	45680	4554	0.227	8.687	5.365	6.801	0.501	5.258
20.00	49683	4829	0.233	8.731	5.425	6.856	0.513	5.300
20.50	54076	5128	0.238	8.794	5.502	6.929	0.526	5.357
21.00	58833	5446	0.244	8.867	5.590	7.013	0.539	5.422
21.50	63886	5776	0.250	8.941	5.677	7.096	0.552	5.486
22.00	69176	6112	0.256	9.006	5.757	7.172	0.565	5.544
22.50	74641	6448	0.261	9.059	5.823	7.234	0.578	5.592
23.00	80245	6782	0.267	9.097	5.873	7.281	0.590	5.629
23.50	85975	7112	0.273	9.121	5.909	7.313	0.603	5.654
24.00	91888	7442	0.279	9.136	5.937	7.338	0.616	5.673

PROGRAM RSP32 RUN BY
AT 10:56:35 ON 10-MAR

MODEL NUMBER 299C
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.
INPUT TAGS N1 = 4 N2

OUTPUT FILENAME: M299
OUTPUT TAGS N1 = 1 N2

PROGRAM RSP32 RUN B: [illegible]
AT 11:01:38 ON 10-MAR-

MODEL NUMBER 299D
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.I
INPUT TAGS N1 = 5 N2 =

OUTPUT FILENAME: M299I
OUTPUT TAGS N1 = 1 N2

TABLE 6
RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299D
FORM FACTOR ANALYSIS
BARE HULL

SHIP LENGTH	200.00 m
DISPLACEMENT	69108 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	2199	450	0.110	6.066	2.261	3.829	0.245	2.218
10.00	2495	485	0.116	5.936	2.168	3.726	0.258	2.158
10.50	2818	522	0.122	5.819	2.087	3.635	0.270	2.106
11.00	3163	559	0.128	5.707	2.009	3.548	0.283	2.055
11.50	3522	595	0.134	5.594	1.927	3.458	0.296	2.003
12.00	3911	634	0.139	5.494	1.857	3.380	0.309	1.958
12.50	4355	677	0.145	5.423	1.814	3.329	0.322	1.928
13.00	4858	726	0.151	5.376	1.794	3.302	0.335	1.912
13.50	5420	780	0.157	5.345	1.788	3.289	0.348	1.905
14.00	6044	839	0.163	5.327	1.794	3.289	0.361	1.905
14.50	6732	902	0.168	5.319	1.809	3.298	0.373	1.910
15.00	7483	970	0.174	5.316	1.829	3.311	0.386	1.918
15.50	8293	1040	0.180	5.315	1.849	3.325	0.399	1.926
16.00	9162	1113	0.186	5.315	1.870	3.340	0.412	1.935
16.50	10093	1189	0.192	5.316	1.890	3.355	0.425	1.943
17.00	11084	1267	0.197	5.316	1.909	3.369	0.438	1.951
17.50	12136	1348	0.203	5.315	1.927	3.381	0.451	1.959
18.00	13254	1431	0.209	5.315	1.944	3.394	0.464	1.966
18.50	14452	1519	0.215	5.318	1.964	3.409	0.476	1.974
19.00	15762	1613	0.221	5.329	1.992	3.432	0.489	1.988
19.50	17229	1717	0.227	5.356	2.034	3.470	0.502	2.010
20.00	18913	1838	0.233	5.405	2.099	3.530	0.515	2.045
20.50	20862	1978	0.238	5.481	2.189	3.616	0.528	2.094
21.00	23026	2131	0.244	5.582	2.290	3.713	0.541	2.150
21.50	25326	2289	0.250	5.650	2.386	3.805	0.554	2.204
22.00	27719	2449	0.256	5.723	2.472	3.887	0.567	2.252
22.50	30202	2609	0.261	5.785	2.548	3.959	0.579	2.293
23.00	32937	2784	0.267	5.859	2.635	4.042	0.592	2.341
23.50	36188	2993	0.273	5.971	2.760	4.164	0.605	2.412
24.00	40264	3261	0.279	6.148	2.949	4.349	0.618	2.519
24.50	45538	3613	0.285	6.414	3.227	4.624	0.631	2.678
25.00	52430	4077	0.290	6.793	3.617	5.011	0.644	2.902
25.50	61343	4676	0.296	7.299	4.134	5.524	0.657	3.200

PROGRAM RSP32 RUN BY
AT 11:05:04 ON 19-MAR-

MODEL NUMBER 299E
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.
INPUT TAGS N1 = 6 N2 =

OUTPUT FILENAME: M299
OUTPUT TAGS N1 = 1 N2

TABLE 7
RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299E
FORM FACTOR ANALYSIS
OUTSIDE WALLS ONLY

SHIP LENGTH	200.00	m
DISPLACEMENT	70009	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
SEA TEMPERATURE	15.0	deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	FNVOL	CTVOL X100
9.50	2667	546	0.110	6.254	2.448	4.016	0.244	2.667
10.00	3094	602	0.116	6.205	2.437	3.995	0.257	2.653
10.50	3581	663	0.122	6.178	2.446	3.995	0.270	2.653
11.00	4131	730	0.128	6.166	2.468	4.007	0.283	2.661
11.50	4743	802	0.134	6.162	2.495	4.026	0.296	2.674
12.00	5419	878	0.139	6.163	2.526	4.049	0.308	2.689
12.50	6164	959	0.145	6.169	2.560	4.075	0.321	2.706
13.00	6981	1044	0.151	6.177	2.595	4.103	0.334	2.725
13.50	7872	1133	0.157	6.187	2.630	4.131	0.347	2.743
14.00	8840	1227	0.163	6.197	2.665	4.159	0.360	2.762
14.50	9888	1326	0.168	6.209	2.700	4.188	0.373	2.781
15.00	11022	1428	0.174	6.222	2.735	4.217	0.385	2.800
15.50	12245	1536	0.180	6.235	2.770	4.246	0.398	2.820
16.00	13558	1647	0.186	6.249	2.804	4.274	0.411	2.838
16.50	14957	1763	0.192	6.260	2.834	4.299	0.424	2.855
17.00	16427	1878	0.197	6.264	2.857	4.317	0.437	2.867
17.50	17951	1994	0.203	6.259	2.870	4.325	0.450	2.872
18.00	19537	2110	0.209	6.247	2.876	4.325	0.463	2.873
18.50	21227	2230	0.215	6.238	2.884	4.329	0.475	2.875
19.00	23158	2369	0.221	6.257	2.919	4.359	0.488	2.895
19.50	25502	2543	0.227	6.327	3.005	4.441	0.501	2.949
20.00	28277	2748	0.232	6.439	3.133	4.564	0.514	3.031
20.50	31386	2976	0.238	6.568	3.277	4.704	0.527	3.124
21.00	34656	3208	0.244	6.686	3.409	4.832	0.540	3.209
21.50	37896	3426	0.250	6.768	3.504	4.923	0.553	3.270
22.00	40962	3619	0.256	6.802	3.552	4.967	0.565	3.299
22.50	43789	3783	0.261	6.789	3.552	4.964	0.578	3.296
23.00	46790	3954	0.267	6.782	3.558	4.965	0.591	3.297
23.50	50483	4176	0.273	6.830	3.619	5.023	0.604	3.335
24.00	54805	4439	0.279	6.918	3.718	5.119	0.617	3.399

TABLE 8

RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299E
FORM FACTOR ANALYSIS
ALL WALLS

SHIP LENGTH	200.00 m
DISPLACEMENT	70719 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
SEA TEMPERATURE	15.0 deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	FNVOL	CTVOL X100
9.50	2905	594	0.110	6.438	2.633	4.201	0.244	2.886
10.00	3356	652	0.116	6.370	2.603	4.161	0.257	2.858
10.50	3865	715	0.122	6.323	2.591	4.139	0.269	2.843
11.00	4434	784	0.128	6.289	2.590	4.130	0.282	2.837
11.50	5064	856	0.134	6.264	2.597	4.129	0.295	2.836
12.00	5774	935	0.139	6.257	2.620	4.143	0.308	2.846
12.50	6585	1024	0.145	6.274	2.664	4.180	0.321	2.871
13.00	7483	1119	0.151	6.297	2.715	4.223	0.334	2.901
13.50	8445	1216	0.157	6.311	2.754	4.255	0.346	2.923
14.00	9462	1314	0.163	6.313	2.781	4.275	0.359	2.937
14.50	10536	1412	0.168	6.306	2.797	4.285	0.372	2.944
15.00	11685	1514	0.174	6.298	2.811	4.293	0.385	2.949
15.50	12938	1623	0.180	6.297	2.832	4.308	0.398	2.959
16.00	14330	1741	0.186	6.312	2.867	4.338	0.410	2.980
16.50	15886	1873	0.192	6.345	2.920	4.385	0.423	3.012
17.00	17558	2008	0.197	6.378	2.971	4.431	0.436	3.044
17.50	19264	2140	0.203	6.390	3.002	4.457	0.449	3.061
18.00	21005	2268	0.209	6.387	3.016	4.466	0.462	3.068
18.50	22828	2399	0.215	6.379	3.026	4.470	0.475	3.071
19.00	24826	2510	0.221	6.385	3.048	4.488	0.487	3.083
19.50	27117	2763	0.227	6.420	3.099	4.534	0.500	3.115
20.00	29812	2897	0.232	6.495	3.189	4.620	0.513	3.174
20.50	32997	3149	0.238	6.613	3.322	4.749	0.526	3.262
21.00	36580	3326	0.244	6.752	3.474	4.897	0.539	3.364
21.50	40302	3644	0.250	6.872	3.609	5.028	0.552	3.454
22.00	43746	3865	0.256	6.928	3.679	5.094	0.564	3.499
22.50	46636	4029	0.261	6.902	3.665	5.076	0.577	3.487
23.00	49522	4185	0.267	6.863	3.639	5.046	0.590	3.467
23.50	53162	4397	0.273	6.886	3.675	5.079	0.603	3.489
24.00	57453	4656	0.279	6.954	3.755	5.156	0.616	3.542

PROGRAM RSP32 RUN BY L
AT 11:07:38 ON 10-MAR-

MODEL NUMBER 299E
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.F
INPUT TAGS N1 = 7 N2 =

OUTPUT FILENAME: M299E
OUTPUT TAGS N1 = 1 N2

TABLE 9
RESULTS OF RESISTANCE EXPERIMENTS

PROGRAM RSP32 RUN BY 6
AT 10:49:45 ON 10-MAR-

MODEL NUMBER 299
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.I
INPUT TAGS N1 = 1 N2 =

OUTPUT FILENAME: M299.
OUTPUT TAGS N1 = 1 N2

MODEL NUMBER 299
POLAR 7
REANALYSIS FOR FORM FACTOR

SHIP LENGTH	199.53 m
DISPLACEMENT	57113 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
FORM FACTOR	1.272
SEA TEMPERATURE	15.0 deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	1110	227	0.110	4.900	0.057	2.052	0.253	1.271
10.00	1282	249	0.116	4.844	0.050	2.032	0.266	1.259
10.50	1475	273	0.122	4.799	0.050	2.021	0.279	1.251
11.00	1691	299	0.128	4.762	0.056	2.015	0.292	1.248
11.50	1930	326	0.134	4.730	0.064	2.012	0.306	1.246
12.00	2192	355	0.140	4.702	0.073	2.011	0.319	1.246
12.50	2478	385	0.145	4.677	0.084	2.012	0.332	1.246
13.00	2793	418	0.151	4.655	0.097	2.016	0.346	1.248
13.50	3139	452	0.157	4.639	0.113	2.023	0.359	1.253
14.00	3519	489	0.163	4.627	0.132	2.034	0.372	1.260
14.50	3933	527	0.169	4.618	0.152	2.046	0.385	1.267
15.00	4384	568	0.174	4.611	0.174	2.060	0.399	1.276
15.50	4878	612	0.180	4.609	0.199	2.077	0.412	1.287
16.00	5421	659	0.186	4.612	0.228	2.099	0.425	1.300
16.50	6018	709	0.192	4.620	0.261	2.124	0.439	1.316
17.00	6677	764	0.198	4.633	0.298	2.155	0.452	1.335
17.50	7406	823	0.204	4.652	0.341	2.191	0.465	1.357
18.00	8202	886	0.209	4.675	0.386	2.230	0.479	1.381
18.50	9064	952	0.215	4.700	0.432	2.270	0.492	1.406
19.00	10001	1023	0.221	4.727	0.480	2.312	0.505	1.432
19.50	11026	1099	0.227	4.758	0.531	2.358	0.518	1.460
20.00	12179	1184	0.233	4.801	0.593	2.414	0.532	1.495
20.50	13505	1281	0.238	4.859	0.670	2.486	0.545	1.540
21.00	15029	1391	0.244	4.933	0.763	2.573	0.558	1.594
21.50	16775	1517	0.250	5.024	0.871	2.676	0.572	1.658
22.00	18790	1660	0.256	5.133	0.998	2.798	0.585	1.733
22.50	21149	1827	0.262	5.267	1.149	2.944	0.598	1.823
23.00	24008	2029	0.267	5.440	1.338	3.129	0.611	1.938
23.50	27542	2278	0.273	5.665	1.579	3.365	0.625	2.084
24.00	31765	2573	0.279	5.933	1.862	3.644	0.638	2.257
24.50	36632	2906	0.285	6.228	2.172	3.950	0.651	2.446
25.00	42205	3282	0.291	6.551	2.510	4.283	0.665	2.653
25.50	48551	3701	0.297	6.901	2.874	4.643	0.678	2.876
26.00	55623	4159	0.302	7.266	3.253	5.018	0.691	3.108

TABLE 10
RESULTS OF RESISTANCE EXPERIMENTS

PROGRAM RSF32 RUN BY L
AT 10:52:36 ON 10-MAR-

MODEL NUMBER 299B
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.I
INPUT TAGS N1 = 3 N2 =

OUTPUT FILENAME: M299I
OUTPUT TAGS N1 = 1 N2

MODEL NUMBER 299B
FORM FACTOR ANALYSIS
GRILLS FITTED

SHIP LENGTH	200.00	m
DISPLACEMENT	70064	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
FORM FACTOR	2.392	
SEA TEMPERATURE	15.0	deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	2704	553	0.110	8.861	-0.241	3.510	0.244	2.702
10.00	3222	626	0.116	8.871	-0.141	3.586	0.257	2.761
10.50	3803	704	0.122	8.879	-0.048	3.657	0.270	2.816
11.00	4450	786	0.128	8.886	0.039	3.722	0.283	2.866
11.50	5168	874	0.134	8.891	0.119	3.782	0.295	2.912
12.00	5959	965	0.139	8.895	0.195	3.838	0.308	2.955
12.50	6827	1062	0.145	8.898	0.265	3.890	0.321	2.995
13.00	7775	1163	0.151	8.900	0.331	3.939	0.334	3.033
13.50	8808	1268	0.157	8.901	0.394	3.985	0.347	3.068
14.00	9931	1379	0.163	8.903	0.453	4.028	0.360	3.102
14.50	11149	1495	0.168	8.905	0.511	4.070	0.373	3.134
15.00	12466	1616	0.174	8.907	0.566	4.111	0.385	3.166
15.50	13888	1742	0.180	8.910	0.620	4.151	0.398	3.196
16.00	15420	1873	0.186	8.914	0.673	4.190	0.411	3.226
16.50	17069	2011	0.192	8.919	0.725	4.229	0.424	3.256
17.00	18844	2155	0.197	8.926	0.778	4.269	0.437	3.287
17.50	20752	2305	0.203	8.936	0.831	4.310	0.450	3.318
18.00	22800	2462	0.209	8.947	0.884	4.351	0.463	3.351
18.50	24996	2626	0.215	8.961	0.938	4.394	0.475	3.383
19.00	27357	2799	0.221	8.978	0.995	4.439	0.488	3.418
19.50	29907	2981	0.227	9.001	1.055	4.489	0.501	3.457
20.00	32656	3174	0.233	9.029	1.120	4.543	0.514	3.498
20.50	35613	3377	0.238	9.061	1.188	4.601	0.527	3.543
21.00	38793	3591	0.244	9.098	1.259	4.662	0.540	3.590
21.50	42221	3817	0.250	9.140	1.334	4.728	0.552	3.641
22.00	45959	4061	0.256	9.192	1.419	4.804	0.565	3.699
22.50	50070	4326	0.261	9.259	1.517	4.893	0.578	3.767
23.00	54526	4608	0.267	9.332	1.621	4.988	0.591	3.841
23.50	59332	4908	0.273	9.412	1.730	5.089	0.604	3.918
24.00	64828	5251	0.279	9.522	1.870	5.220	0.617	4.019
24.50	71425	5667	0.285	9.688	2.064	5.406	0.630	4.162
25.00	79027	6145	0.290	9.892	2.296	5.629	0.642	4.335

TABLE 11
RESULTS OF RESISTANCE EXPERIMENTS

PROGRAM RSP32 RUN BY
AT 10:55:15 ON 10-MAR

MODEL NUMBER 299B
FORM FACTOR ANALYSIS
NO GRILLS FITTED

MODEL NUMBER 299A
CONDITION NUMBER 2
TEST NUMBER 0

INPUT FILENAME: M299.
INPUT TAGS N1 = 2 N2

OUTPUT FILENAME: M299
OUTPUT TAGS N1 = 2 N2

SHIP LENGTH	200.00	m
DISPLACEMENT	70044	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
FORM FACTOR	2.016	
SEA TEMPERATURE	15.0	deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	FNVOL	CTVOL X100
9.50	2082	426	0.110	7.504	-0.168	2.993	0.244	2.082
10.00	2478	482	0.116	7.509	-0.086	3.055	0.257	2.124
10.50	2924	541	0.122	7.515	-0.009	3.114	0.270	2.165
11.00	3423	605	0.128	7.523	0.066	3.170	0.283	2.205
11.50	3981	673	0.134	7.532	0.139	3.226	0.296	2.244
12.00	4599	745	0.139	7.543	0.210	3.281	0.308	2.281
12.50	5282	821	0.145	7.554	0.278	3.333	0.321	2.318
13.00	6033	902	0.151	7.566	0.344	3.385	0.334	2.354
13.50	6857	987	0.157	7.579	0.409	3.435	0.347	2.389
14.00	7760	1077	0.163	7.594	0.473	3.486	0.360	2.424
14.50	8748	1173	0.168	7.611	0.537	3.537	0.373	2.460
15.00	9824	1273	0.174	7.630	0.600	3.588	0.385	2.495
15.50	10990	1378	0.180	7.649	0.662	3.638	0.398	2.530
16.00	12250	1488	0.186	7.668	0.722	3.686	0.411	2.564
16.50	13611	1603	0.192	7.687	0.782	3.735	0.424	2.597
17.00	15085	1725	0.197	7.710	0.842	3.785	0.437	2.632
17.50	16686	1853	0.203	7.736	0.905	3.838	0.450	2.669
18.00	18415	1989	0.209	7.765	0.970	3.892	0.463	2.707
18.50	20273	2130	0.215	7.795	1.034	3.947	0.475	2.745
19.00	22281	2279	0.221	7.829	1.101	4.004	0.488	2.784
19.50	24468	2439	0.227	7.870	1.173	4.067	0.501	2.829
20.00	26840	2609	0.232	7.916	1.250	4.135	0.514	2.876
20.50	29399	2788	0.238	7.965	1.329	4.206	0.527	2.925
21.00	32159	2977	0.244	8.018	1.412	4.280	0.540	2.977
21.50	35154	3178	0.250	8.078	1.499	4.360	0.552	3.032
22.00	38460	3398	0.256	8.151	1.599	4.452	0.565	3.096
22.50	42162	3643	0.261	8.242	1.717	4.562	0.578	3.173
23.00	46234	3907	0.267	8.345	1.846	4.684	0.591	3.257
23.50	50645	4189	0.273	8.454	1.980	4.810	0.604	3.345
24.00	55579	4502	0.279	8.582	2.132	4.956	0.617	3.446
24.50	61258	4860	0.285	8.744	2.318	5.134	0.630	3.571
25.00	67628	5258	0.290	8.928	2.525	5.335	0.642	3.710

PROGRAM RSP32 RUN BY W
AT 10:58:48 ON 10-MAR-

MODEL NUMBER 299C
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.I
INPUT TAGS N1 = 4 N2 =

OUTPUT FILENAME: M299C
OUTPUT TAGS N1 = 1 N2

TABLE 12
RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299C
FORM FACTOR ANALYSIS .
GRILLS FITTED

SHIP LENGTH	200.00 m
DISPLACEMENT	70506 t
DRAUGHT	14.03 m
TRIM BY STERN	0.00 m
MODEL SCALE	46.0000
CORRELATION ALLOWANCE	0.00000
FORM FACTOR	2.339
SEA TEMPERATURE	15.0 deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	2654	543	0.110	8.651	-0.250	3.418	0.244	2.642
10.00	3166	615	0.116	8.663	-0.149	3.495	0.257	2.702
10.50	3738	692	0.122	8.671	-0.058	3.564	0.270	2.755
11.00	4371	772	0.128	8.675	0.024	3.625	0.282	2.803
11.50	5070	857	0.134	8.676	0.098	3.680	0.295	2.845
12.00	5837	945	0.139	8.674	0.166	3.729	0.308	2.883
12.50	6673	1038	0.145	8.669	0.227	3.772	0.321	2.916
13.00	7584	1134	0.151	8.662	0.283	3.811	0.334	2.946
13.50	8573	1234	0.157	8.654	0.335	3.847	0.347	2.974
14.00	9642	1339	0.163	8.646	0.383	3.879	0.359	2.999
14.50	10793	1447	0.168	8.635	0.427	3.908	0.372	3.021
15.00	12034	1559	0.174	8.626	0.470	3.936	0.385	3.043
15.50	13376	1677	0.180	8.619	0.513	3.965	0.398	3.065
16.00	14823	1801	0.186	8.614	0.556	3.995	0.411	3.089
16.50	16379	1930	0.192	8.611	0.599	4.025	0.424	3.112
17.00	18058	2065	0.197	8.612	0.644	4.058	0.436	3.137
17.50	19878	2208	0.203	8.618	0.693	4.094	0.449	3.165
18.00	21841	2359	0.209	8.628	0.744	4.134	0.462	3.196
18.50	23947	2516	0.215	8.641	0.796	4.175	0.475	3.228
19.00	26225	2683	0.221	8.659	0.852	4.221	0.488	3.263
19.50	28718	2863	0.227	8.687	0.918	4.275	0.501	3.305
20.00	31488	3060	0.232	8.731	0.997	4.345	0.513	3.359
20.50	34593	3280	0.238	8.794	1.095	4.433	0.526	3.427
21.00	38004	3518	0.244	8.867	1.202	4.530	0.539	3.502
21.50	41654	3766	0.250	8.941	1.308	4.627	0.552	3.577
22.00	45481	4019	0.256	9.006	1.406	4.715	0.565	3.645
22.50	49423	4270	0.261	9.059	1.489	4.790	0.578	3.703
23.00	53443	4517	0.267	9.097	1.557	4.849	0.590	3.749
23.50	57526	4758	0.273	9.121	1.610	4.893	0.603	3.783
24.00	61728	5000	0.279	9.136	1.654	4.929	0.616	3.811

PROGRAM RSP32 RUN BY
AT 11:02:48 ON 10-MAR

MODEL NUMBER 299D
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.I
INPUT TAGS N1 = 5 N2 =

OUTPUT FILENAME: M299I
OUTPUT TAGS N1 = 1 N2

TABLE 13
RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299D
FORM FACTOR ANALYSIS
BARE HULL

SHIP LENGTH	200.00	m
DISPLACEMENT	69108	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
FORM FACTOR	1.504	
SEA TEMPERATURE	15.0	deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	EN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	1551	317	0.110	6.066	0.343	2.702	0.245	1.565
10.00	1750	340	0.116	5.936	0.269	2.613	0.258	1.513
10.50	1965	364	0.122	5.819	0.206	2.535	0.270	1.468
11.00	2193	388	0.128	5.707	0.145	2.460	0.283	1.425
11.50	2426	410	0.134	5.594	0.079	2.382	0.296	1.379
12.00	2678	434	0.139	5.494	0.024	2.314	0.309	1.340
12.50	2975	463	0.145	5.423	-0.005	2.274	0.322	1.317
13.00	3320	496	0.151	5.376	-0.012	2.257	0.335	1.307
13.50	3713	535	0.157	5.345	-0.004	2.253	0.348	1.305
14.00	4156	577	0.163	5.327	0.014	2.262	0.361	1.310
14.50	4653	624	0.168	5.319	0.041	2.279	0.373	1.320
15.00	5199	674	0.174	5.316	0.072	2.301	0.386	1.332
15.50	5792	726	0.180	5.315	0.103	2.323	0.399	1.345
16.00	6432	781	0.186	5.315	0.134	2.345	0.412	1.358
16.50	7120	839	0.192	5.316	0.164	2.367	0.425	1.371
17.00	7856	898	0.197	5.316	0.193	2.388	0.438	1.383
17.50	8638	959	0.203	5.315	0.219	2.407	0.451	1.394
18.00	9472	1023	0.209	5.315	0.245	2.425	0.464	1.405
18.50	10372	1090	0.215	5.318	0.273	2.446	0.476	1.417
19.00	11370	1163	0.221	5.329	0.309	2.475	0.489	1.434
19.50	12509	1247	0.227	5.356	0.360	2.519	0.502	1.459
20.00	13850	1346	0.232	5.405	0.433	2.585	0.515	1.497
20.50	15441	1464	0.238	5.481	0.530	2.676	0.528	1.550
21.00	17231	1595	0.244	5.567	0.638	2.778	0.541	1.609
21.50	19140	1730	0.250	5.650	0.742	2.876	0.554	1.666
22.00	21126	1867	0.256	5.722	0.835	2.963	0.567	1.716
22.50	23185	2003	0.261	5.795	0.917	3.039	0.579	1.760
23.00	25479	2153	0.267	5.859	1.010	3.127	0.592	1.811
23.50	28272	2339	0.273	5.971	1.142	3.253	0.605	1.884
24.00	31872	2581	0.279	6.148	1.337	3.443	0.618	1.994
24.50	36652	2908	0.285	6.414	1.621	3.722	0.631	2.156
25.00	43032	3346	0.290	6.793	2.016	4.113	0.644	2.382
25.50	51414	3919	0.296	7.299	2.539	4.630	0.657	2.682

TABLE 14

RESULTS OF RESISTANCE EXPERIMENTS

PROGRAM RSP22 RUN BY
AT 11:06:11 ON 10-MAR

MODEL NUMBER 299E
FORM FACTOR ANALYSIS
OUTSIDE WALLS ONLY

NODEL NUMBER 299E
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.
INPUT TAGS N1 = 5 N2 =

OUTPUT FILENAME: M299
OUTPUT TAGS N1 = 1 N2

SHIP LENGTH	200.00	m
DISPLACEMENT	70009	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
FORM FACTOR	1.652	
SEA TEMPERATURE	15.0	deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	1698	348	0.110	6.254	-0.033	2.558	0.244	1.698
10.00	1979	385	0.116	6.205	-0.019	2.555	0.257	1.697
10.50	2305	427	0.122	6.178	0.013	2.571	0.270	1.707
11.00	2680	474	0.128	6.166	0.056	2.600	0.283	1.726
11.50	3102	524	0.134	6.162	0.104	2.634	0.296	1.749
12.00	3574	579	0.139	6.163	0.154	2.671	0.308	1.774
12.50	4100	638	0.145	6.169	0.207	2.710	0.321	1.800
13.00	4680	700	0.151	6.177	0.259	2.751	0.334	1.827
13.50	5318	766	0.157	6.187	0.311	2.791	0.347	1.853
14.00	6016	835	0.163	6.197	0.362	2.831	0.360	1.880
14.50	6777	908	0.168	6.209	0.412	2.870	0.373	1.906
15.00	7605	986	0.174	6.222	0.461	2.909	0.385	1.932
15.50	8504	1066	0.180	6.235	0.510	2.949	0.398	1.958
16.00	9474	1151	0.186	6.249	0.557	2.986	0.411	1.983
16.50	10509	1239	0.192	6.260	0.601	3.021	0.424	2.006
17.00	11596	1326	0.197	6.264	0.636	3.048	0.437	2.024
17.50	12717	1413	0.203	6.259	0.661	3.064	0.450	2.035
18.00	13879	1499	0.209	6.247	0.678	3.073	0.463	2.041
18.50	15123	1589	0.215	6.238	0.697	3.084	0.475	2.048
19.00	16586	1697	0.221	6.257	0.743	3.122	0.488	2.073
19.50	18440	1838	0.227	6.327	0.839	3.211	0.501	2.132
20.00	20702	2012	0.232	6.439	0.977	3.341	0.514	2.219
20.50	23274	2207	0.238	6.568	1.131	3.488	0.527	2.317
21.00	25984	2405	0.244	6.686	1.272	3.623	0.540	2.406
21.50	28640	2589	0.250	6.768	1.377	3.721	0.553	2.471
22.00	31097	2748	0.256	6.802	1.433	3.771	0.565	2.504
22.50	33291	2876	0.261	6.789	1.442	3.774	0.578	2.506
23.00	35632	3011	0.267	6.782	1.456	3.781	0.591	2.511
23.50	38639	3196	0.273	6.830	1.525	3.844	0.604	2.553
24.00	42249	3422	0.279	6.918	1.633	3.946	0.617	2.621

PROGRAM 65P3: RUN 81 4
AT 11:08:29 ON 10-MAR

MODEL NUMBER 299F
CONDITION NUMBER 1
TEST NUMBER 0

INPUT FILENAME: M299.F
INPUT TAGS N1 = 7 N2 =

OUTPUT FILENAME: M299F
OUTPUT TAGS N1 = 1 N2

TABLE 15
RESULTS OF RESISTANCE EXPERIMENTS

MODEL NUMBER 299F
FORM FACTOR ANALYSIS
ALL WALLS

SHIP LENGTH	200.00	m
DISPLACEMENT	70719	t
DRAUGHT	14.03	m
TRIM BY STERN	0.00	m
MODEL SCALE	46.0000	
CORRELATION ALLOWANCE	0.00000	
FORM FACTOR	1.683	
SEA TEMPERATURE	15.0	deg C

TEST DATE
SHIP IN SALT WATER
BLOCKAGE CORRECTION APPLIED

VS knots	PE KW	R KN	FN	CTM(15) X1000	CR X1000	CTS X1000	ENVOL	CTVOL X100
9.50	1848	378	0.110	6.438	0.033	2.673	0.244	1.836
10.00	2139	416	0.116	6.370	0.030	2.652	0.257	1.822
10.50	2472	458	0.122	6.323	0.042	2.648	0.269	1.819
11.00	2851	504	0.128	6.289	0.064	2.656	0.282	1.824
11.50	3275	554	0.134	6.264	0.093	2.670	0.295	1.834
12.00	3762	609	0.139	6.257	0.136	2.699	0.308	1.854
12.50	4332	674	0.145	6.274	0.199	2.750	0.321	1.889
13.00	4973	744	0.151	6.297	0.268	2.806	0.334	1.928
13.50	5659	815	0.157	6.311	0.325	2.852	0.346	1.959
14.00	6382	886	0.163	6.313	0.368	2.883	0.359	1.981
14.50	7142	957	0.168	6.306	0.400	2.905	0.372	1.995
15.00	7958	1031	0.174	6.298	0.429	2.923	0.385	2.008
15.50	8857	1111	0.180	6.297	0.465	2.949	0.398	2.026
16.00	9874	1200	0.186	6.312	0.514	2.989	0.410	2.053
16.50	11035	1300	0.192	6.345	0.580	3.046	0.423	2.092
17.00	12288	1405	0.197	6.378	0.645	3.101	0.436	2.130
17.50	13554	1506	0.203	6.390	0.688	3.136	0.449	2.154
18.00	14832	1603	0.209	6.387	0.714	3.153	0.462	2.166
18.50	16169	1699	0.215	6.379	0.735	3.166	0.475	2.175
19.00	17657	1806	0.221	6.385	0.768	3.192	0.487	2.193
19.50	19413	1935	0.227	6.420	0.830	3.246	0.500	2.230
20.00	21548	2094	0.232	6.495	0.931	3.340	0.513	2.294
20.50	24149	2290	0.238	6.613	1.074	3.475	0.526	2.387
21.00	27121	2510	0.244	6.752	1.236	3.631	0.539	2.494
21.50	30205	2731	0.250	6.872	1.380	3.768	0.552	2.589
22.00	32985	2914	0.256	6.928	1.459	3.841	0.564	2.638
22.50	35183	3040	0.261	6.902	1.455	3.830	0.577	2.631
23.00	37350	3157	0.267	6.863	1.437	3.806	0.590	2.615
23.50	40242	3329	0.273	6.886	1.482	3.845	0.603	2.641
24.00	43785	3546	0.279	6.954	1.570	3.927	0.616	2.698

FIGURE 1

PROTECTION OF PROPELLERS IN ICE

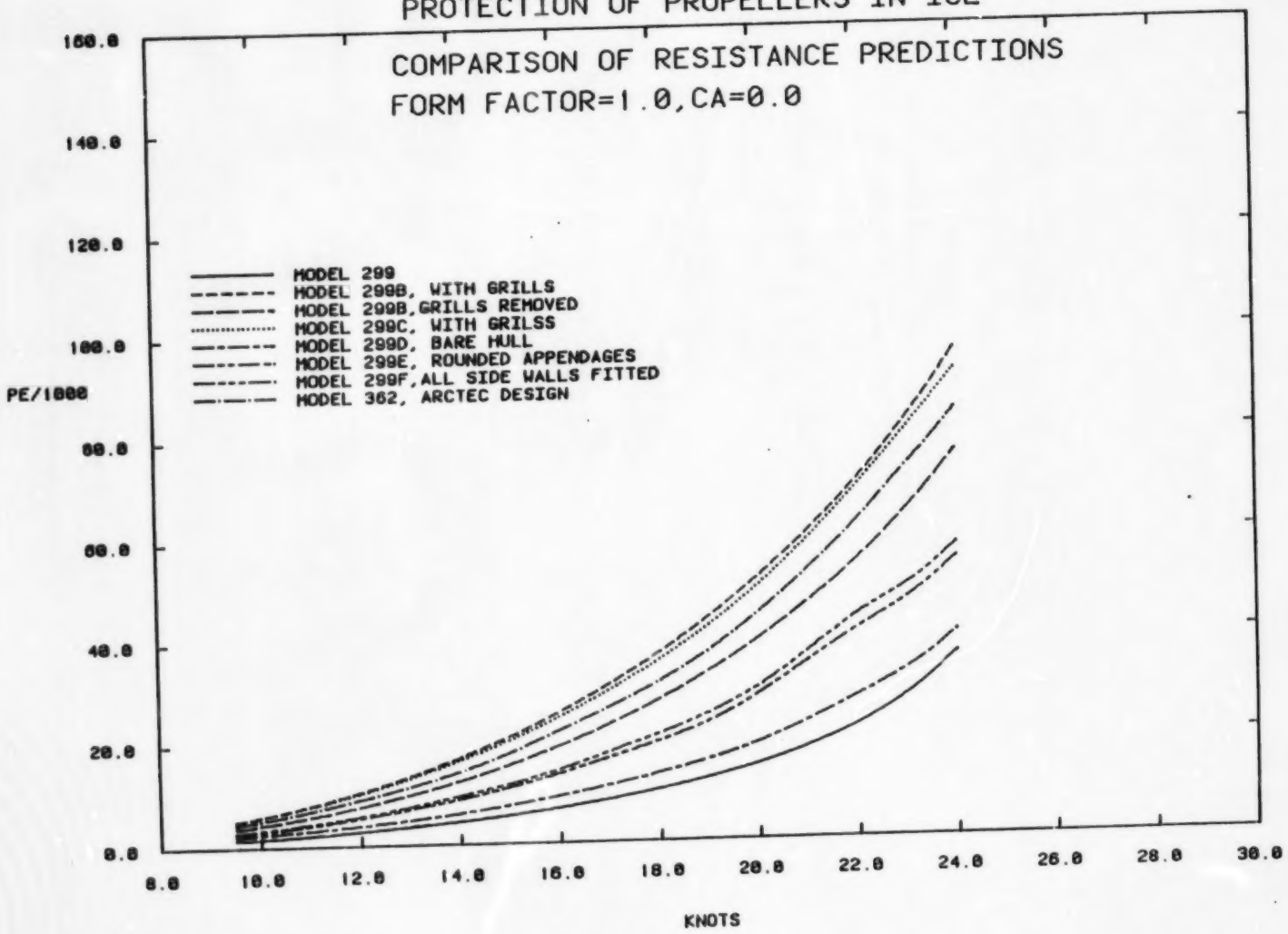

FIGURE 2

PROTECTION OF PROPELLERS IN ICE

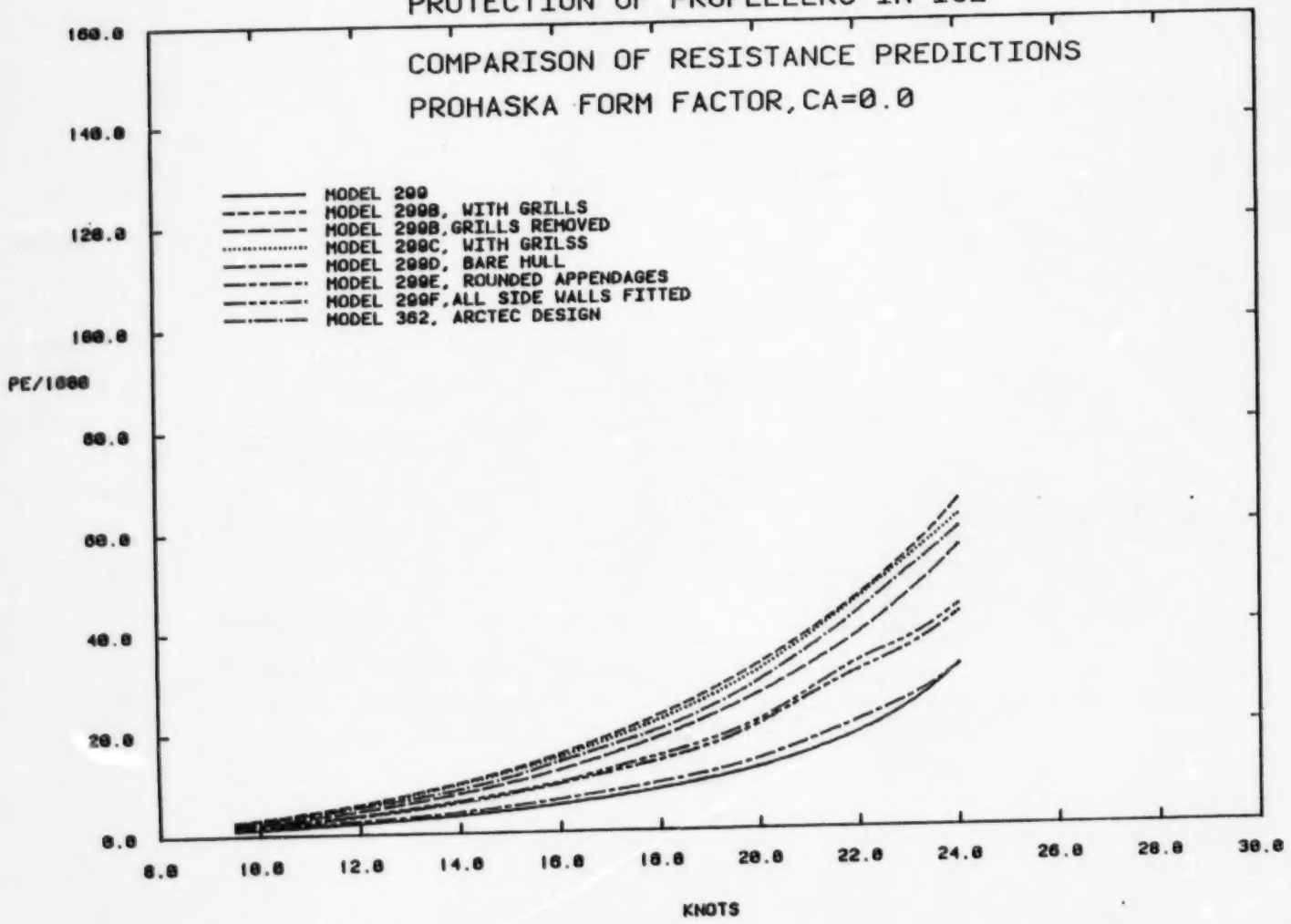

FIGURE 3

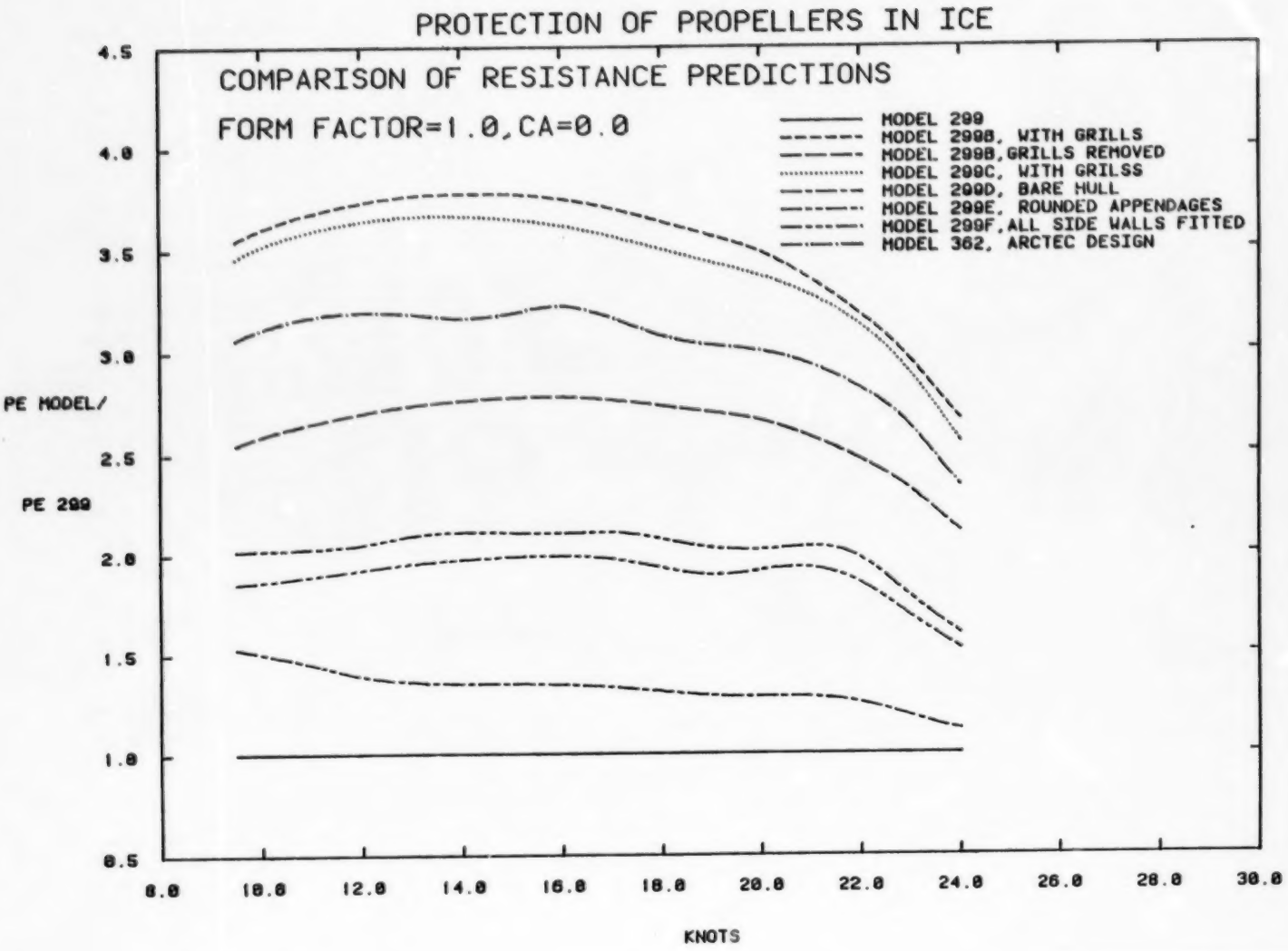
PROTECTION OF PROPELLERS IN ICE
COMPARISON OF RESISTANCE PREDICTIONS
FORM FACTOR=1.0,CA=0.0
MODEL 299
MODEL 299B, WITH GRILLS
MODEL 299B,GRILLS REMOVED
MODEL 299C, WITH GRILSS
MODEL 299D, BARE HULL
MODEL 299E, ROUNDED APPENDAGES
MODEL 299F,ALL SIDE WALLS FITTED
MODEL 362, ARCTEC DESIGN
PE MODEL/
PE 299
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
KNOTS

FIGURE 4

PROTECTION OF PROPELLERS IN ICE